IDAHO
DEPARTMENT OF FISH & GAME

Jerry M. Conley, Director

FEDERAL AID TO FISH & WILDLIFE RESTORATION

Job Performance Report

Project F-73-R-2

SUBPROJECT III: LAKE & RESERVOIR INVESTIGATIONS

Study V. Coeur d'Alene Lake Fisheries Investigations

Period Covered: 1 March 1979 to 29 February 1980

by

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September, 1980

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Coeur d'Alene Lake Fisheries Investigations

Job 1. Coeur d'Alene Lake Creel Census by

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Job 2. Coeur d'Alene Lake Limnology

by

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Job 3. Kokanee Life History Studies in Coeur d'Alene Lake by

Bert Bowler
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Coeur d'Alene Lake Spawning Evalutions

by

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Graduate Research Assistant

and

Bruce E. Rieman
Senior Fishery Research Biologist

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INTRODUCTION

Coeur d'Alene Lake is located in the Idaho panhandle. It is the second largest lake in the state with a surface area of 12,743 ha (31,475 acres). The lake is 46 km (24 mi) long and has a shoreline length of 202 km (109 mi). Mean depth is 24 m (79 ft) and maximum recorded depth is 61 m (200 ft). The major tributaries, the St. Joe and Coeur d'Alene Rivers enter in the southern portion of the lake. The Spokane River on the north end is the only outlet. The long axis of the lake lies north-south along the direction of the prevailing winds.

A dam was constructed on the outlet at Post Falls in 1903 and is operated by the Washington Water Power Company. The normal maximum pool elevation is 649 m (2,128 ft) above sea level. Typically the lake is drawn down 1 to 2.5 m (3.3 to 8.2 ft) during the fall and winter months for power production.

Development in the drainage basin and along the lakeshore has been extensive and cultural eutrophication of the system has been obvious. Phosphorous loadings are high and the lake has generally been considered meso-trophic. Heavy metal pollution from the Coeur d' Alene Mining District on the South Fork of the Coeur d'Alene River has also been present since the late 1800s. High zinc concentrations have been found in the water column, but much of the metal pollution may be absorbed by suspended inorganic material and transported to the lake sediments.

Despite its pollution problems, Coeur d'Alene Lake has historically supported excellent fisheries. Westslope cutthroat (*Salmo clarki lewisi*) are native to the system and supported the major fishery in the lake prior to the 1960s. Kokanee were introduced in 1937 from embryos collected in the Pend Oreille Lake system. A few hundred thousand fry were planted annually during the 1940s and early 1950s and a modest kokanee fishery developed. In the late 1950s annual releases were generally increased and ranged from several hundred thousand fish to over a million. The kokanee fishery improved and with a declining cutthroat population, kokanee made up over 40% of the harvest in 1960. By 1967 kokanee represented 98% of the Coeur d'Alene harvest. At that time it was still felt that natural reproductive success was poor and that the fishery was sustained artificially. During the early 1970s attempts were made to establish early-spawning kokanee from Anderson Ranch Reservoir in tributaries to build a self-sustaining population. The early race apparently contributed very little to the fishery or spawning runs. The fishery continued to increase, however. By the mid-1970s Coeur d'Alene had developed a high yield handline fishery reminiscent of past seasons on Pend Oreille. In 1978 preliminary acoustic and trawl sampling indicated that the lake had a very high density population, with total numbers of kokanee in the system of approximately 7 million. It was obvious that the population was self-sustaining.

A research program was initiated in 1979 to study the system and document the current status of the fishery. We felt that data on a strong kokanee population would be valuable in interpreting and understanding important factors affecting declining stocks in Pend Oreille and Priest Lakes. Management data was also necessary to maintain the current productivity of the Coeur d'Alene fishery.

ACKNOWLEDGMENTS

The following people contributed significantly to field work, sample and data analysis and report preparation: Shere Chroninger, Anna Marie Halpern, Pete Hassemer, Larry LaBolle, Lloyd McGee and Connie Williams. The Idaho Department of Health and Welfare provided laboratory facilities for analysis of chlorophyll samples. The Washington Water Power Company provided salary for Larry LaBolle.

JOB PERFORMANCE REPORT

State of	Idaho	Name:	LAKE AND RESERVOIR INVESTIGATIONS
Project No.	F-73-R-2	Title:	Coeur d'Alene Lake Creel Census
Study No.	V		
Job No.	I		

Period Covered: 1 March 1979 to 29 February 1980

ABSTRACT

A boat count type creel census was conducted on Coeur d'Alene Lake during 1979. The lake supported a high yield fishery for kokanee. An estimated total of 282,837 angler hours was expended to harvest 578,034 kokanee. A major portion of the harvest occurred early in the season when handlining was good. The spring handline and shoreline kokanee fishery was due to high densities of kokanee and provided a unique fishing opportunity.

The 3+ age class of kokanee appeared to be weak and fishing was not as good as anticipated. A stronger cohort should be available to the fishery in 1980.

Estimated exploitation of age 3+ kokanee was 47% in 1979. The high exploitation may have been due to the weak year-class, but it is also possible that exploitation will remain stable or even increase with a stronger year-class. Additional harvest information is necessary to describe the functional response of the fishery.

A reduction of harvest may be necessary in the future to prevent over-exploitation in Coeur d'Alene Lake. Several management options in seasons regulation exist that would be useful in restricting harvest.

The Coeur d'Alene Lake kokanee population probably cannot support a major predator and high exploitation. Anglers were opposed to Kamloops introduction.

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RECOMMENDATIONS

1. The high density of kokanee in Coeur d'Alene Lake supports a unique hand-line and shoreline fishery. This type of fishery adds to the diversity of angling opportunity and the value of the fishery to the local community. Any increase in the size of kokanee in Coeur d' Alene would likely require a major reduction in the size of the population probably at the expense of the handline fishery. Efforts should be made to maintain the current high densities of kokanee in the Coeur d'Alene system.

2. Estimated exploitation on Coeur d'Alene Lake was high in 1979. It is not known whether the observed exploitation is typical of this system or if it was the product of a weak year-class. We also do not know what level of exploitation can be sustained by this population. Because we do not know how exploitation rate will vary as a function of stock size the creel census should be continued during 1980 when a strong year-class will be available to the fishery. Additional population data should be collected to estimate annual mortality. The resulting estimates of exploitation and stock productivity may be used to estimate sustainable exploitation and harvest.

3. Because exploitation on Coeur d'Alene was high, additional fishing pressure and harvest should not be encouraged. If exploitation is considered excessive several options in more restrictive regulations exist. A major reduction in harvest could be obtained by closure of fishing until after mid-May. Some harvest reduction would result by closure of the whole lake or even section 1 during September. Reduction in limits may be useful but then it is not possible to predict the reduction in harvest.

4. With a high rate of exploitation, the Coeur d'Alene Lake kokanee population probably cannot support the additional loss to a major predator and maintain the current population density. Angler opinion was opposed to the introduction of the Kamloops. Predator introductions should not be considered at this time.

OBJECTIVES

To estimate the angler use and harvest of the Coeur d'Alene Lake fisheries. To

provide length, weight and scale samples of fish in the catch.

TECHNIQUES USED

Creel Census

The creel census used on Coeur d'Alene Lake in 1979 was a boat count type, similar to that used on Priest Lake by Rieman and Lukens (1979). The census was stratified by interval of the season, day type (weekday or weekend and holiday) time of day and area of the lake. The census was initiated in late April before any significant fishing pressure was observed and terminated in early November (when effort became insignificant). Fifteen census intervals, 14 days in length, were used to stratify the season. During each interval 2 weekdays and 2 weekend days were selected randomly as census days. All legal holidays were also included as census days. We assumed a fishing day lasted from sunrise to sunset and determined the mean number of daylight hours for each interval with the Farmer's Almanac (Table 1). We

Table 1 . Dates and mean day length for 15 census intervals on Coeur d'Alene Lake, 1979.

Interval	Dates	Mean daylight hours
1	15 April - 28 April	14.0
2	29 April - 12 May	14.5
3	13 May - 26 May	15.5
4	27 May - 9 June	16.0
5	10 June - 23 June	16.0
6	24 June - 7 July	16.0
7	8 July - 21 July	16.0
8	22 July - 4 August	15.0
9	5 August - 18 August	14.5
10	19 August - 1 September	13.5
11	2 September - 15 September	13.0
12	16 September - 29 September	12.0
13	30 September - 13 October	11.5
14	14 October - 27 October	10.5
15	28 October - 10 November	10.0

then divided each census day into three periods, as morning, mid-day and afternoon. A boat count of the entire lake was made at varied hours within each of the three periods.

The lake was divided into three sections for each count (Fig. 1). Chatcolet Lake was also included as a fourth section during the first half of the season. During each count the number of fishing boats not in transit (people in the act of fishing) and shoreline anglers in each section was noted. We also recorded the number of non fishing boats to determine the relative fishing--nonfishing recreational boat use on Coeur d'Alene. At the end of each interval we calculated the mean number of boats and shoreline anglers per day by lake section. This was done separately for each day type. Multiplying these figures by the number of daylight hours for the interval provided an estimate of the mean boat and shoreline angler hours per day type. These multiplied by the number of weekend days, weekdays and holidays resulted in an estimate of boat hours and shoreline hours for the interval. In addition to boat counts we interviewed as many anglers as possible throughout each interval to determine catch rate, number of kokanee taken per angler on the last trip and mean number of anglers per boat. By combining these with the previous estimate of hours we were able to estimate harvest by interval and lake section.

During some angler contacts we also included two questions. The first was to determine angler opinion regarding the introduction of Gerrard rainbow (*Salmo gairdneri*) from Pend Oreille to Coeur d'Alene Lake. That question was worded as follows:

> "There is some consideration of introducing Kamloops (the large rainbow from Pend Oreille) to Coeur d'Alene Lake. Because they are a predator on kokanee it could mean some reduction in the number of kokanee available to anglers. Would you be in favor of, or opposed to such an introduction?"

The second question was asked to determine whether any conflicts were involved with the apparently heavy boat use on Coeur d'Alene. It was worded as follows:

> "Do the number of boats on Coeur d'Alene Lake interfere with your use of the lake?"

Catch Composition

We took a length of at least 100 fish in the catch at monthly intervals during 1979. By comparing these length frequencies with length frequencies of known age fish from trawl samples (Bowler 1980) we were able to estimate the age composition of the catch. We also used the length-weight relationship developed from trawl sampling to estimate biomass of the catch.

FINDING

S Effort

During 1979 anglers expended an estimated 282,837 hours on Coeur d'Alene Lake. The fishing effort was directed almost entirely toward kokanee, with only 0.7% (2,069 hr) of the total specifically for cutthroat or other species. Effort was relatively even between the north and mid-lake sections but slightly higher on the south end (Table 2). Eleven percent of the total effort was expended by shore anglers, with most of this occurring during the spring handlining season (through interval 6)

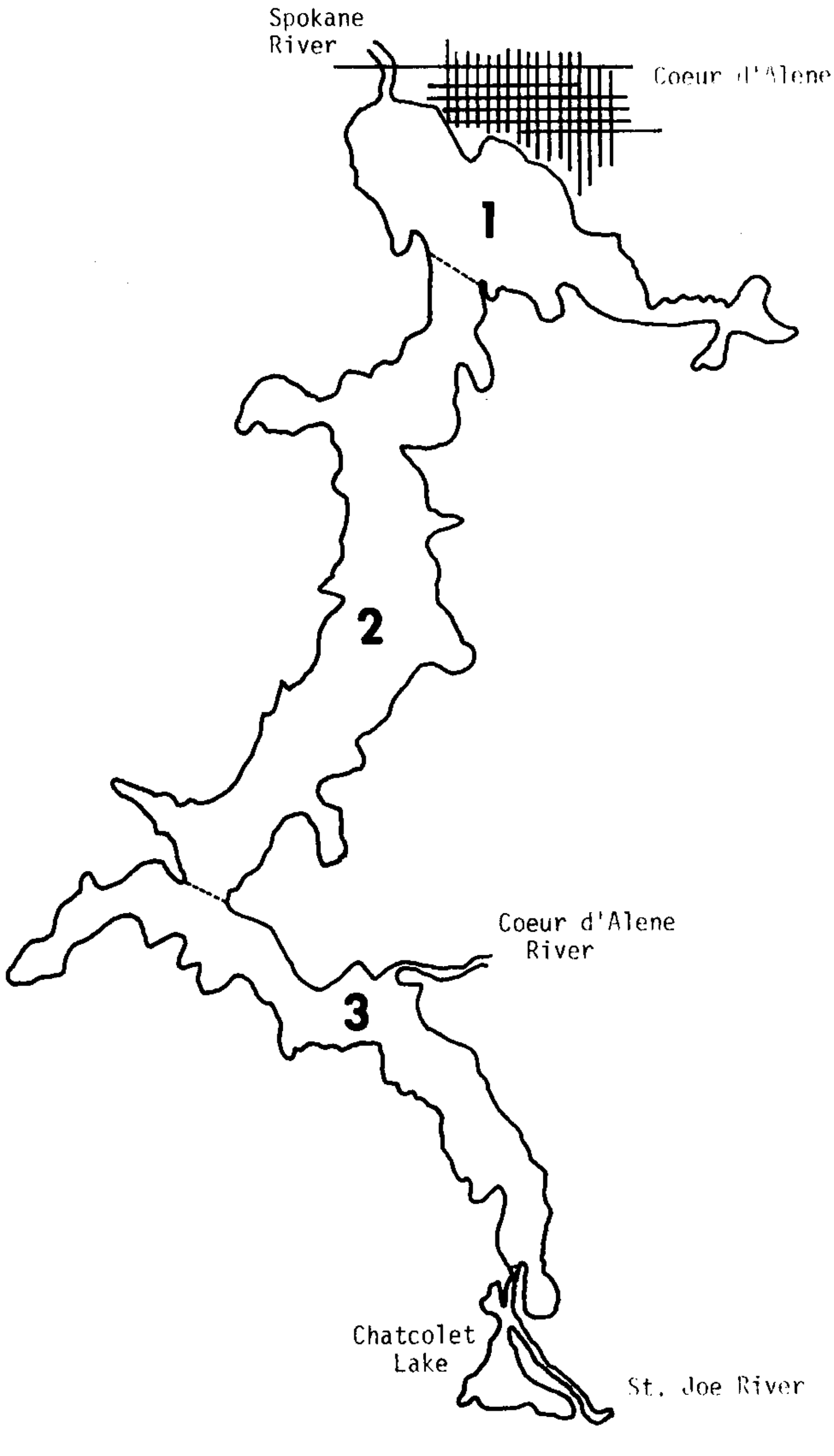

Figure 1. Coeur d'Alene Lake, Idaho with creel census sampling areas for 1979.

Table 2. Total angler effort' and kokanee harvest[2] on Coeur d'Alene Lake, Idaho, 1979.

	Section 1	Section 2	Section 3	Total
Angler effort (hours)				
Boat	73,167	68,850	109,037	251,054
Shore	11,872	17,494	2,417	31,783
Total	85,039	86,344	111,454	282,837
Kokanee harvest				
Boat	125,356	165,848	185,958	477,162
Shore	35,570	56,769	8,533	100,872
Total	160,926	222,617	194,491	578,034

1. Almost entirely for kokanee, an estimated 2,069 hours were expended specifically for cutthroat.

2. In addition an estimated 595 cutthroat and 1,150 perch were harvested.

(Appendix A). Most of the shore fishing was in the north and mid-lake sections. Fishing hours peaked during the spring handlining season (Fig. 2). Almost half of the total season effort occurred in intervals 3 and 4 (mid-May--mid-June). Fishing effort on Coeur d'Alene in 1979 was roughly 70% higher than the 1967 estimate of 169,907 hours (Mallet 1968).

Harvest

We estimate that anglers harvested 578,034 kokanee from Coeur d'Alene Lake in 1979. Approximately 17% of those (100,872) were taken by shore anglers during the period of good handlining early in the season. Estimated harvest of kokanee was highest in the mid-lake section and lowest in the northern section (Table 2). A major portion of the kokanee harvest was taken during May and June (Fig. 3). We estimate that approximately 60% of the total catch was taken by handlining during that period. Harvest declined during the summer and then picked up slightly during the fall. Most of the harvest during census intervals 12, 13 and 14 was in the northern section of the lake (Appendix B). The kokanee harvest estimate in 1979 was 2.4 times the 242,207 estimated catch in 1967 (Mallet 1968).

From length frequency samples we estimate that 34% (192,272) of the catch was age 2+ kokanee while age 3+ fish made up the difference. The proportion of age 2+ and 3+ fish in the catch was roughly even early in the year but the contribution of age 2+ declined through the season. The catch was virtually 100% mature (3+) fish by fall (Fig. 3). With this information, estimated yield was 48,943 kg (107,773 lb) of which 80% was from age 3+ fish. Total yield for the lake was 3.84 kg/ha (3.42 lb/ acre).

A comparison of length frequency of the catch early in the season was similar for 1976, 1977 and 1978. The 1979 sample indicated a higher proportion of age 2+ fish than in the three previous seasons and was similar to the 1975 sample. The 1974 sample indicates a higher proportion of much larger fish than in any of the subsequent years (Fig. 4).

During our census we found some cutthroat and perch taken incidentally in the kokanee fishery. The standard census estimates indicate that 595 cutthroat and 1,150 perch were taken by Coeur d'Alene kokanee fishermen during 1979.

Success

Catch rates from angler interviews averaged 2.04 kokanee per hour during 1979. Although there was variation, success was generally similar between census sections (Appendix C). Catch rate peaked during the spring handline fishery, declined during the summer (except for an increase during interval 8) and increased again during the fall (Fig. 5). The average number of kokanee taken per angler trip followed a similar seasonal trend ranging from approximately 16 fish/angler in the spring to less than 10 during summer (Fig. 6). The percentage of anglers taking limits was high in the spring (34-38%), declined during the summer and increased slightly again in fall (Fig. 7).

Fishing success appeared to be better in 1979 than during 1967 when Mallet (1968) recorded an average catch rate of 1.42 kokanee/hour. A comparison of kokanee catch rates during the peak spring period for 1974 and 1976-1979 indicated that fishing success during 1979 was higher than in any year but 1978 (Table 3).

During 1979 angler effort and each of the three success indices (fish/hr, fish/ angler and % angler limits) followed the same general trend of high in the spring,

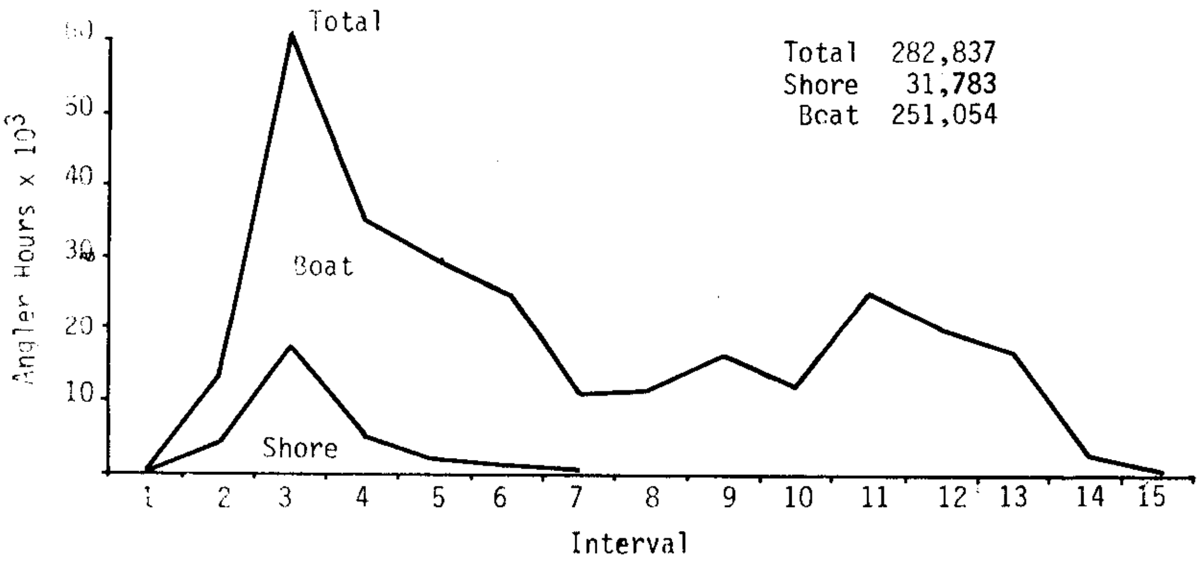

Figure 2. Angler hours per two-week census interval on Coeur d'Alene Lake, Idaho 1979.

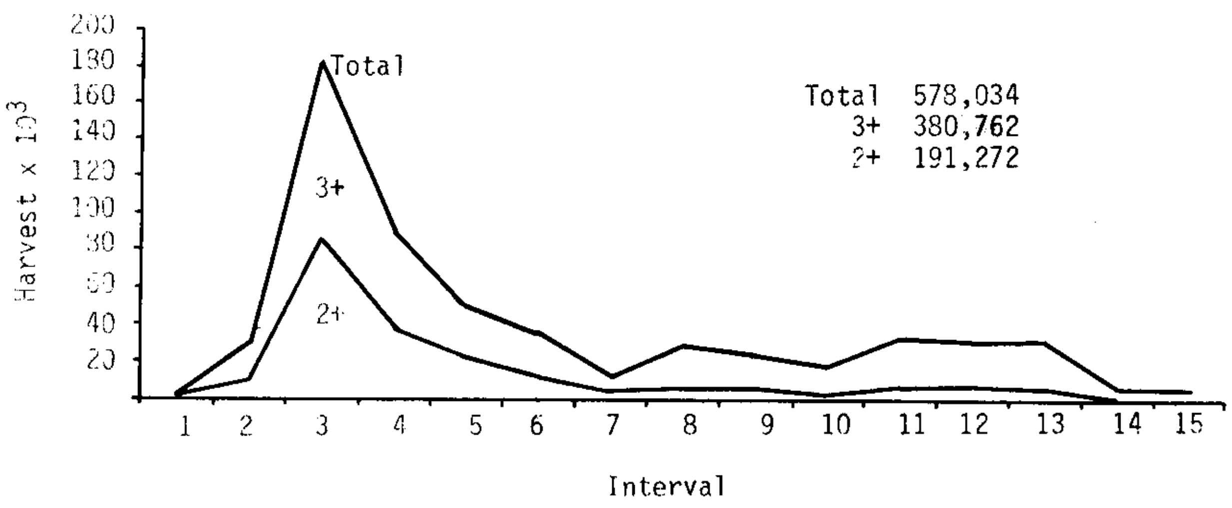

Figure 3. Angler harvest of kokanee by two-week census interval on Coeur d'Alene Lake,Idaho 1979.

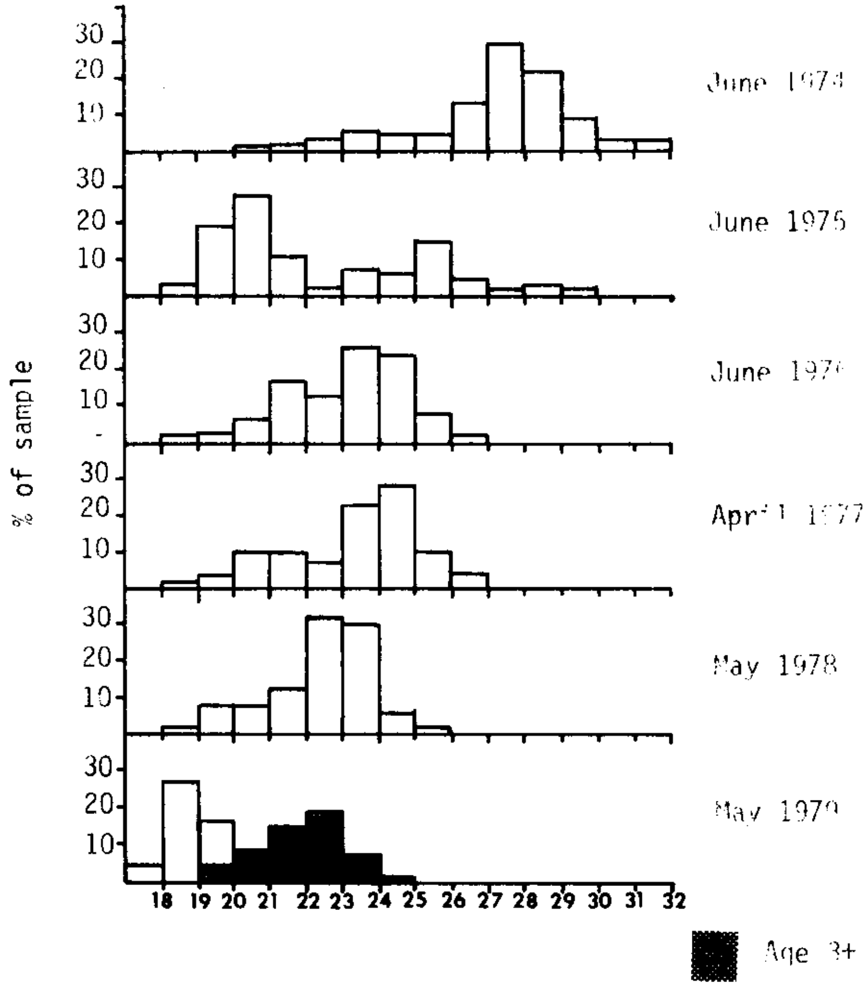

Figure 4. Length frequency of kokanee in the spring fishery on Coeur d'Alene Lake, Idaho 1974-1979.

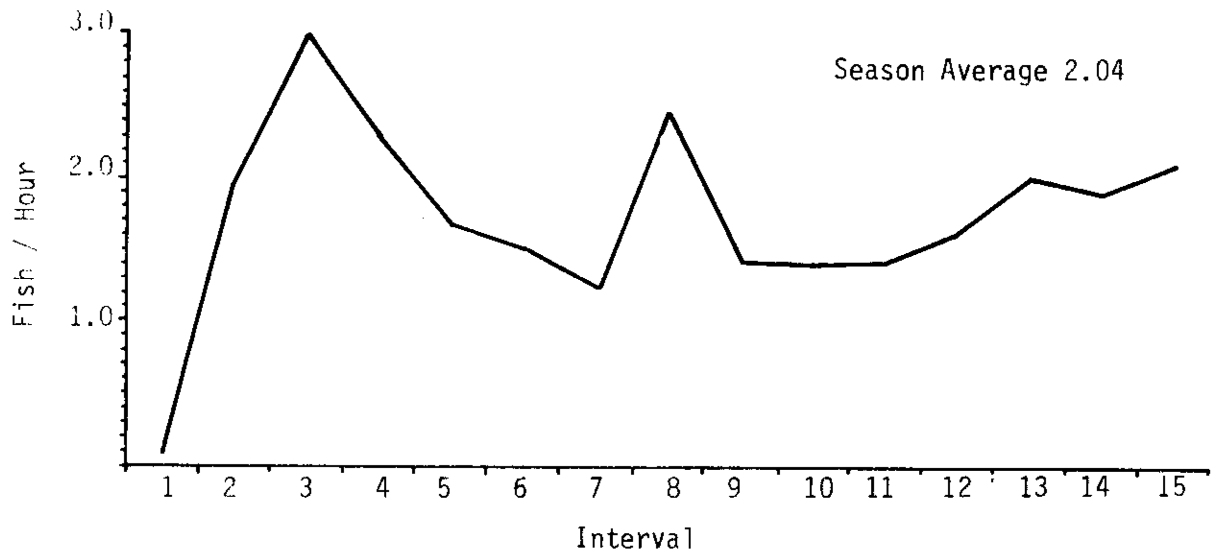

Figure 5. Catch per angler hour by two-week interval on Coeur d'Alene Lake, Idaho 1979.

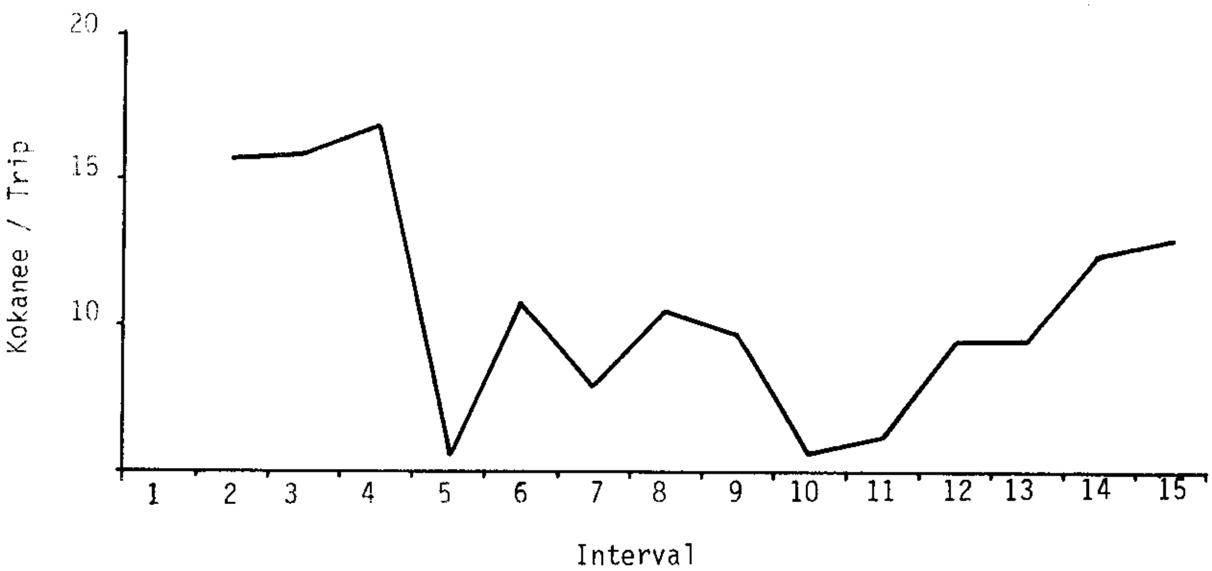

Figure 6. Kokanee per angler trip by two-week interval on Coeur d'Alene Lake, Idaho 1979

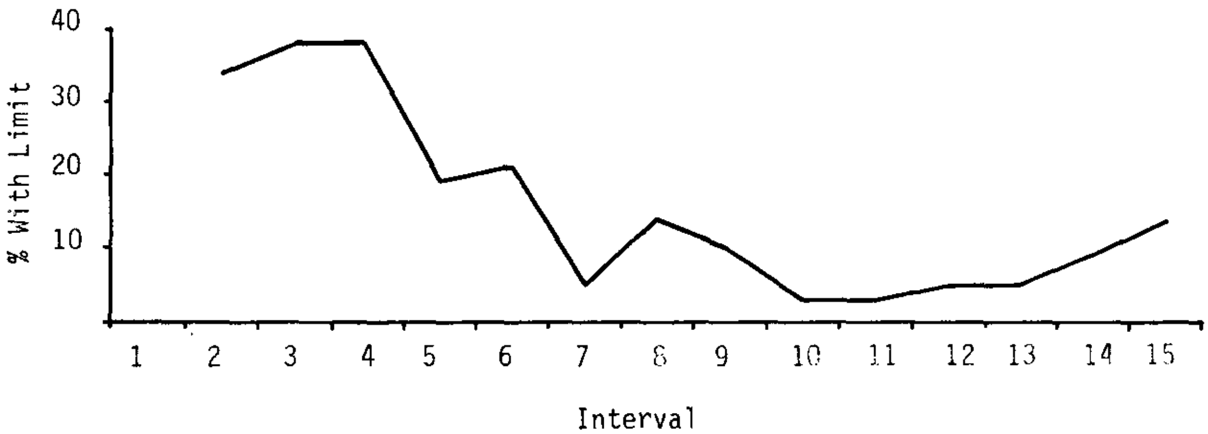

Figure 7. Proportion of anglers reporting limits by two-week census interval on Coeur d'Alene Lake, Idaho 1979.

Table 3. Angler catch rates for kokanee during the spring "peak" period (May-early June) in Coeur d'Alene Lake, Idaho, 1974, 1976-1979.

Year	Kokanee/hour
1974	1.5
1976	2.0
1977	1.6
1973	3.0
1979	2.7

low in summer, increasing again in fall. A correlation matrix indicates that effort was significantly (p = .05) and positively related to catch rate and frequency of limits. Each index of success was significantly related to the others (Table 4).

Angler Composition and Opinion

The residency of 992 Coeur d'Alene Lake anglers was recorded and of these 81% (802) were Idaho residents. We obtained 444 responses to the question on Kamloops introduction. The majority (51%) were opposed to such an introduction, 33% were in favor and 16% had no opinion. We obtained only 64 responses to the boat interference question. Eighty percent (51) of that sample felt there was no problem, 14% (9) felt the number of boats on the lake did interfere with their use and 6% (4) had no opinion.

Recreational Boat Use

The recreational boat use on Coeur d'Alene Lake was classified as fishing or nonfishing during the census boat counts. Fishing made up the major portion (80%) of boat use during the season (Appendix D). Nonfishing boat use was greatest during the summer period, peaking during July and August.

Chatcolet Lake

The Coeur d'Alene creel census was expanded to include Chatcolet Lake during the first seven census intervals (through 21 July). A significant kokanee and perch handline fishery existed on Chatcolet during that period. An estimated 19,966 angler hours were expended to harvest 40,368 kokanee and 5,958 perch. Average catch rates during the period were 2.0 kokanee/hour and 0.3 perch/hour (Table 5).

DISCUSSION

The estimated cutthroat harvest on Coeur d'Alene Lake was low, but similar to the 889 fish harvest estimated by Mallet for 1967. Virtually all of our estimated catch of cutthroat was taken incidentally by kokanee fishermen. It is very likely that the actual cutthroat harvest on Coeur d'Alene Lake was considerably higher than our estimate. A lot of cutthroat fishing takes place near the outlet of the Spokane River and in isolated shoreline areas during the spring. The census, designed primarily to estimate kokanee harvest, did not take those areas into account.

In addition to cutthroat and perch, crappie, bullheads and bass were also taken by fishermen on Coeur d'Alene. For the same reasons described above we could not make reasonable estimates for these fisheries.

Coeur d'Alene was obviously a productive kokanee fishery in 1979. Catch rates were high and comparable to those measured on Pend Oreille Lake during years of good fishing (Ellis and Bowler 1979). Estimated yield (3.84 kg/ha) also appeared to he high. Based on the morphoedophic index (Ryder 1965) a yield of 1.5 kg/ha (1.4 lb/ acre) would be predicted for Coeur d'Alene. From chlorophyll data yield could be expected at approximately 3 kg/ha (Oglesby 1977). Harvest has increased substantially since 1967, but catch rates have improved also. The data definitely indicates an increase in population size since that time.

One important difference in the Coeur d'Alene fishery since 1967 has been the development of a substantial handline fishery in the spring. handlining appears Lo be related to high densities of fish. Pend Oreille Lake supported an active winter

Table 4. Correlation coefficients (r) relating census interval values of effort, catch rate, frequency of limits and catch per angler from Coeur d'Alene Lake, Idaho, 1979.

	Kokanee/h	% with limit	Kokanee/angler
Effort	*.58	*.66	.41
Kokanee/h	--	*.68	*.83
with limit	--	--	*.78

*significant at p = .05

Table 5. Estimate angler hours, harvest and catch rate on Chatcolet Lake, Idaho in 1979.

Interval	Angler hours	Harvest			Fish/hour	
		Kokanee	Perch	Crappie	Kokanee	Perch
1	0	0	0	--	--	--
2	426	664	0	--	1.6	0
3	2,314	3,993	3,298	--	1.7	1.4
4	5,284	11,775	961	--	2.2	0.2
5	8,203	17,817	1,329	--	2.2	0.2
6	3,411	6,119	370	48	1.8	0.1
7	328	--	--	--	--	--
Total	19,966	40,368	5,958	--	2.0	0.3

and spring handline fishery prior to the mid 1970s, but that fishery has become nonexistent with the recent decline in that kokanee population. The development of handlining on Coeur d'Alene may be a function of an increasing kokanee population and also an influx of handline fishermen from Pend Oreille Lake. A unique aspect of the Coeur d'Alene spring fishery was the availability of kokanee to handliners fishing from the shoreline and docks. A significant part of the effort and harvest was from the shoreline fishery. The ability of fishermen to take kokanee effectively without a boat undoubtedly enhances the diversity and value of the resource to the local community.

Total angler effort on Coeur d'Alene in 1979 was high. With 282,837 hours expended during one season the Coeur d'Alene kokanee fishery is undoubtedly one of the most important fisheries in the state. An estimate of the mean angler day of 5.7 hours was made from the average number of kokanee caught/angler and catch rate. Using that figure Coeur d' Alene supported 49,620 angler days in 1979. Using a value of $24/angler day (Gordon et al. 1973) and a consumer price index of 2.3 (December 1979), the net economic value of the Coeur d'Alene Lake fishery in 1979 was $2,739,000.

Even though kokanee fishing in 1979 was good, it was not as good as we had anticipated. There was also some comment by fishermen that success was not as good as the previous season. The spring catch rates were lower than in 1978, and were also lower than those recorded on Pend Oreille during peak fishing years (Ellis and Bowler 1979). Length frequency analyses from the catch indicate that a large portion of the spring catch was age 2+ kokanee. Comparison with data from earlier years indicate that the contribution of age $^{3+}$ fish was less than in past seasons except 1975. The data suggests that the 3+ age class was weak in 1979 perhaps a result of weak spawning population in 1976. Data from trawl sampling in 1978 and 1979 supports that conclusion (Bowler 1980). It would appear that a stronger age class will be available to the fishery in 1980.

The 1979 population estimate on Coeur d'Alene Lake in September was 425,444 age 3+ and 1,587,597 age 2+ kokanee (Bowler 1980). Assuming that nonfishing mortality during the summer was 0, exploitation was estimated at 47% for age 3+ fish and 9% for age 2+. That appears to be a high rate of exploitation. We do not know what level of exploitation this population can support and we will need
several years of population estimates and subsequent mortality estimates to simulate the stock recruitment relationship. It is likely, however, that 50% exploitation is quite significant and may in fact be overharvest for maintaining a stable population. The high exploitation in 1979 could have been due to the weak 3+ age class. With a strong age 3+ cohort in 1980, exploitation may decline. It is also possible that exploitation may remain stable or even increase. With a higher density of fish, success should improve. Bowler has shown a positive relationship between catch rate and density of kokanee available to the fishery. If effort remains stable, an increase in catch rate could in itself increase harvest and maintain the high exploitation. The relationships between success and angler effort also suggests that better fishing could lead to increasing participation in the fishery. The result could be higher exploitation. Obviously we do not understand the functional response of the Coeur d'Alene Lake fishery. Additional years of creel census with fluctuating stock size would be valuable in describing this relationship. If exploitation on Coeur d' Alene is consistently high and/or increasing it is likely that increased restriction will be necessary in the near future to maintain the population.

If more restrictive regulations become necessary several management options are available with seasons. A major portion of the harvest occurs early in the season.

A late opening date could be effective in reducing harvest. Approximately 20% of the harvest of mature fish also occurred late in the season. If fishing had been closed in mid-September exploitation on age 3+ fish could theoretically have been reduced from 47% to 38%. A significant reduction in harvest might also be possible by closure of only part of the lake. Because most of the spawning occurs on the northern end of the lake, mature fish (and anglers) began congregating in that area in the fall. Harvest of mature kokanee remained at a moderate level during that time while it declined in the other sections. Roughly 14% of the harvest of mature fish could have been eliminated by closing section 1 in mid-September. New regulations altering kokanee limits might also be effective in reducing the harvest. During spring a large proportion (up to 38%) of anglers reported taking limits. Reduced limits could reduce the harvest but the magnitude is impossible to predict.

During 1979 anglers voiced some complaint about the "small size" of kokanee they were catching. While there is some evidence that the kokanee population in Coeur d'Alene Lake was approaching carrying capacity (Rieman 1980) it does not appear that growth has declined significantly in the last few years. Growth of Coeur d'Alene kokanee appears better than those from Pend Oreille. The apparent smaller size of kokanee in 1979 was due to the weak 3+ age class. As a result the smaller age 2+ kokanee (which also appeared to be a strong year-class) made up a larger proportion of the catch than in the past few years. Average size of kokanee caught did actually decline.

If the Coeur d'Alene Lake population is approaching carrying capacity, size of mature fish could decline if the population continued to increase. At the same time, however, our concept of density dependent response in kokanee (Rieman 1979, and this report-limnology) suggests that a decline in population size would not result in any substantial increase in growth and size of spawners. To significantly increase the size of kokanee taken in the catch a very large reduction in population size might be necessary. Any increase in kokanee size might come at the expense of the relatively high catch rates and the unique handline fishery.

Coeur d'Alene Lake supports a substantial kokanee population that could serve as forage for a large predator. Some interest has developed in the past to intro-duce Gerrard rainbow in hope of providing a trophy fishery. Most anglers felt they would not want to risk losing the highly productive kokanee fishery and were opposed to such introductions. In the case of the shoreline fishery many anglers did not own a boat and would have no means of fishing for the trout. With the high exploitation in the Coeur d'Alene Lake fishery such introduction might well be a risk. The population probably could not support the present level of fishing with a significant loss to predation as well.

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Appendix A. Estimated fishing effort (angler hours) by two-week census interval on three sections of Coeur d'Alene Lake, Idaho, 1979.

Interval	Section 1		Section 2		Section 3		Total
	Boat	Shore	Boat	Shore	Boat	Shore	
1	168	--	112	--	158	--	438
2	1,425	1,131	5,892	3,190	2,191	--	13,830
3	11,957	5,642	18,546	9,931	12,863	1,633	60,623
4	6,079	2,438	6,439	2,806	17,134	459	35,358
5	4,305	1,461	4,797	746	1,566	133	29,444
6	4,666	970	5,875	439	13,243	97	25,291
7	1,811	69	2,824	40	6,188	66	11,000
8	2,412	160	2,547	270	6,261	20	11,671
9	4,187		3,177	19	9,058	10	16,452
10	4,985		1,981		5,565		12,532
11	8,456		6,158		10,789		25,404
12	10,508		4,758		5,557		20,824
13	8,261		4,877		3,752		16,891
14	2,227		569		378		3,175
15	1,715		291		233		2,240

Appendix B. Estimated harvest of kokanee by two-week census interval on three sections of Coeur d'Alene Lake, Idaho, 1979.

Interval	Section 1 Boat	Section 1 Shore	Section 2 Boat	Section 2 Shore	Section 3 Boat	Section 3 Shore	Total
1	37	0	0	0	0	0	37
2	884	1,764	17,442	4,976	2,191	0	27,257
3	17,338	25,406	63,427	44,947	22,897	7,351	181,366
4	23,529	4,145	21,637	4,771	29,472	780	84,334
5	4,435	2.557	7,100	1.306	33.982	232	49.614
6	10,032	1,698	6,111	769	19,203	170	37,983
7	1,902		2,345		9,221		13,468
8	2,436		5,630		19,474		27,540
9	3,685		3,876		16,033		23,594
10	7,529		3,546		6,511		17,586
11	12,178		11,701		12,408		36,287
12	18,074		9,603		6,558		34,235
13	16,006		11,682		6,716		34,404
14	3,666		1,131		799		5,596
15	3,625		617		493		4,735

Appendix C. Estimated catch rate (fish/hour) for kokanee by two-week census interval on three sections of Coeur d'Alene Lake, Idaho, 1979.

Interval	Section 1		Section 2		Section 3		X
	Boat	Shore	Boat	Shor	Boat	Shore	
1	0.2						0.1
2	0.6	1.6	3.0	1.6	1.0	1.6	2.0
3	1.5	4.5	3.4	4.5	1.8	4.5	3.0
4	3.9	1.7	3.4	1.7	1.7	1.7	2.4
5	1.0	1.8	1.5	1.8	2.2	1.8	1.7
6	2.2		1.0		1.5		1.5
7	1.1		0.8		1.5		1.2
8	1.0		2.2		3.1		2.5
9	0.9		1.2		1.8		1.4
10	1.5		1.8		1.2		1.4
11	1.4		2.0		1.2		1.4
12	1.7		2.0		1.2		1.6
13	1.9		2.4		1.8		2.0
14	1.7		2.0		2.1		1.8
15	2.1						2.1

Appendix D. Relative recreational boat use (fish vs non-fishing) by two-week census interval on Coeur d'Alene Lake, Idaho, 1979.

Interval	Holidays & Weekends		Weekdays		Weighted % of total	
	Fishing	Non-fishing	Fishing	Non-fishing	Fishing	Non-fishing
1	2.3	0.0	0.0	0.0	100.0	0
2	7.7	0.0	6.4	0.0	100.0	0
3	46.6	--	12.6	0.2	99.6	0.4
4	33.8	1.6	5.8	0.0	96.1	3.9
5	22.8	6.7	15.2	0.9	83.3	16.7
6	16.3	4.7	13.4	2.9	79.6	20.4
7	11.2	15.9	8.1	1.6	52.4	47.6
8	9.7	13.2	8.1	2.6	52.9	47.1
9	18.3	10.2	11.0	2.6	69.7	30.3
10	23.3	--	6.5	1.9	94.0	6.0
11	16.3	5.1	25.1	9.3	74.1	25.9
12	26.0	10.0	18.7	0.6	80.9	19.1
13	28.8	0.1	13.3	6.7	86.2	13.8
14	5.2	2.1	2.8	0.3	76.6	23.4
15	3.3	0.0	7.0	0.0	100.0	0
Mean	18.1	5.8	10.3	2.0	80%	20%

JOB PERFORMANCE REPORT

Period Covered: I March 1979 to 29 February 1980

ABSTRACT

A study was conducted on Coeur d'Alene Lake during 1979 to describe its limnological characteristics and relate them to the abundance, growth, survival and distribution of kokanee.

Coeur d'Alene was described as a mesotrophic system though chlorophyll values were not as high as might be expected from available nutrient data. An oxygen deficit exists during the summer. Coupled with thermal stratification, low oxygen may eliminate habitat for kokanee on the south end of the lake. Further eutrophication will aggravate that loss.

Zooplankton biomass was similar to that observed on Pend Oreille and Priest Lakes. The availability of food for kokanee may have been better than those lakes since the preferred prey was much more abundant.

Wolf Lodge Bay was a unique part of the lake. Zooplankton production occurred earlier and was higher in that area than in other parts of the lake. The higher availability of food during the period of fry recruitment may have been an important factor making Wolf Lodge the major fry producing area on the lake.

Growth of age 1+, 2+ and 3+ kokanee and the proportion of age 0+ kokanee with food in the gut was directly related to zooplankton biomass. There appeared to be a threshold of food densities below which growth did not occur and fry could not or would not feed. Such a threshold might be used as a simple index of the suit-ability of lakes to support kokanee and for optimal timing of fry releases.

Estimated cropping of the zooplankton did not appear high but there was some evidence that the level of cropping did result in reduction in the mean size of preferred prey organisms. The Coeur d'Alene Lake kokanee population may have been approaching the food determined carrying capacity of the system.

Age 0 kokanee tended to use different food items than older kokanee. It is likely that they are also spacially segregated from the older fish. Direct competition between fry and older fish is probably minor. Compensatory factors regulating the productivity of the kokanee population are probably more closely related to density dependent responses in growth and fecundity of adult kokanee than to any response in growth and survival of fry.Author:

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Senior Fishery Research Biologist

RECOMMENDATIONS

1. An obvious oxygen deficit occurs in Coeur d'Alene Lake. Coupled with thermal stratification this may periodically eliminate kokanee habitat in the southern part of the lake. Further eutrophication will aggravate the oxygen deficit and loss of habitat and may increase the concentrations of dissolved heavy metals, damaging the fishery. Further cultural development of the Coeur d'Alene watershed that may increase nutrient input should be opposed.

2. Wolf Lodge Bay represents a unique part of Coeur d'Alene Lake with higher food production during the period of fry recruitment than in the rest of the lake or in Pend Oreille Lake. This is probably a major factor making Wolf Lodge the major fry producing area on Coeur d'Alene. The integrity of this area and its watershed including Blue, Wolf Lodge and Beauty Creeks should be protected.

3. The initial feeding of emergent kokanee fry appears to be related to the density of preferred prey such as Bosmina. The data indicates a threshold level of 10 to 20 mg/m^3 is necessary for all fry to feed. This level should be used as a preliminary index to time future releases of artifically incubated and reared fry for kokanee enhancement programs. Further research with artificial enclosures should be used to refine this index so that use of hatchery systems can be made as efficient as possible while still providing maximum fry survival.

OBJECTIVES

To describe seasonal trends in limnological characteristics of Coeur d'Alene Lake, including water temperature, primary and secondary production.

To relate the limnological characteristics to kokanee feeding, growth, distribution and abundance.

TECHNIQUES USED

Limnological sampling was conducted in three areas of Coeur d'Alene Lake (Fig. 1) during 1979. Samples were collected once in April, September and November, and twice monthly from May through August. Temperature profiles were recorded with a bathytherniograph. Chlorophyll "a" was measured from composite samples of the upper 12 m (39.4 ft) of the water column (sample depths = 0 m, 3 m, 6 m, 9 m and 12 m). Chlorophyll samples were analyzed as described by U.S.E.P.A. (1973). Secchi transparency was measured with a standard 20 cm (7.9 in) disk. Dissolved oxygen profiles were recorded on 6 September with a YSI D.O. meter.

Zooplankton samples were collected with a 1/2-m ring net using a 130 ,um mesh net (4:1 OAR) and bucket. The net was volumetrically calibrated using a non-reversing flow meter mounted in the mouth. The net was towed vertically from 30 m (98.4 feet) (or the bottom in shallower water) to surface at approximately 1 m/sec with a hand winch. Two to five samples were collected in each sampling section. One sample was always collected in Wolf Lodge Bay. Samples were pre-served in 3% formalin. Enumeration by species was done by standard sub-sampling and counting techniques (Edmondson 1971). Samples collected from areas less than 30 m deep were assumed to be from 30 m to eliminate a sample volume bias. Each entire sample was sorted for counting Leptodora kindtii. Dry weight biomass esti-

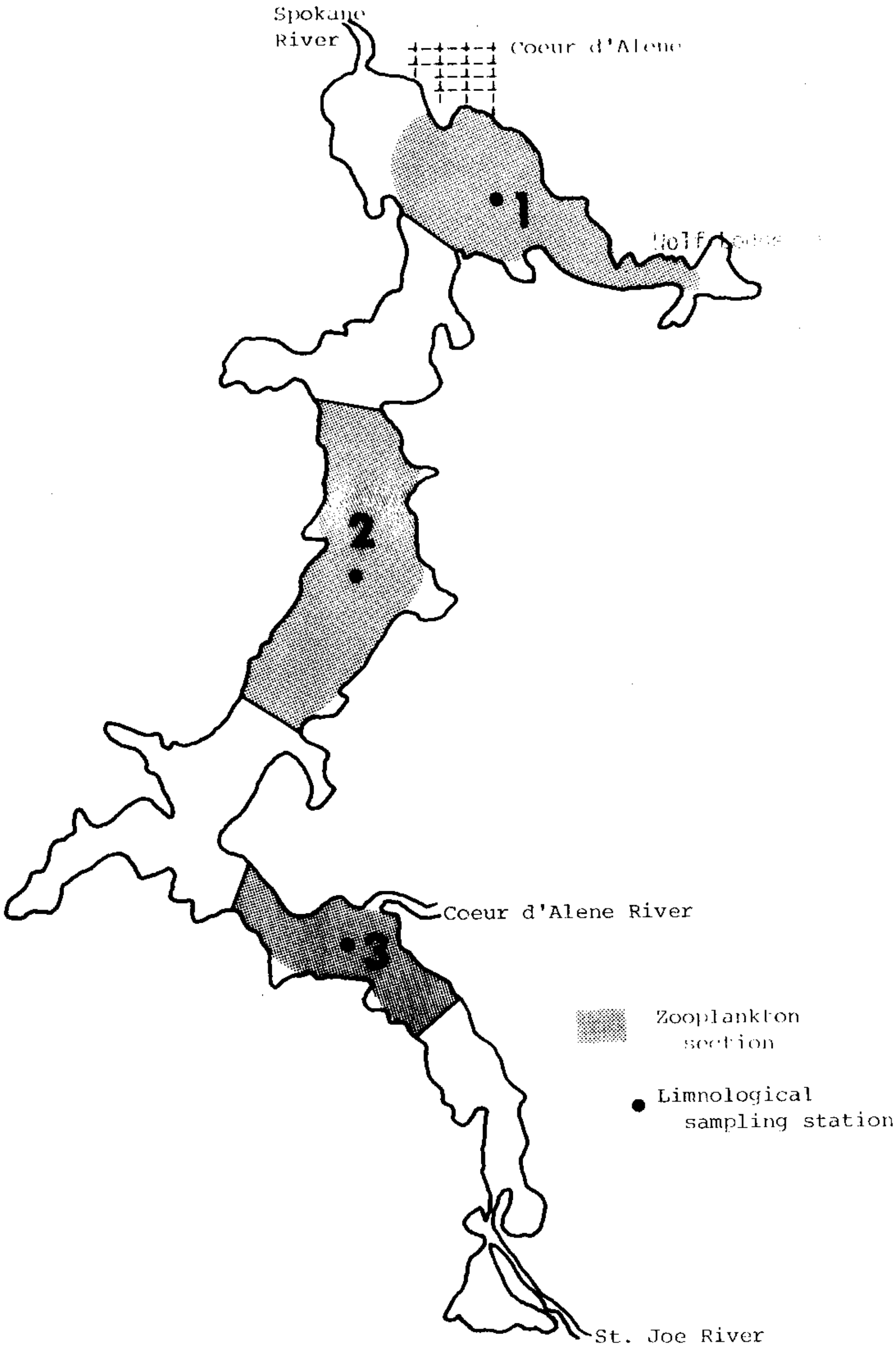

Figure 1. Limnological sampling areas on Coeur d'Alene Lake, Idaho 1979.

mates were made from a single composite of all samples. Fifty individuals of each species were measured on a calibrated scale projector and individual weight was estimated from established length-weight relationships (Pechen 1965, Klekowski and Shuskina 1966). Total biomass estimates for Pend Oreille Lake have been made by actual measurement of individual samples. Measured biomass has consistently averaged 70% of estimated biomass, probably due to weight loss from formalin preservation in the measured samples. Therefore, for comparative purposes, all biomass values presented here have been corrected, and are 70% of the original calculated values.

Kokanee stomachs for food habits were collected from mid-water trawl samples on a monthly basis from May through October (Bowler 1980). Stomach samples were generally taken only early in the evening to eliminate loss due to digestion (Rieman 1979). For analysis the material from stomach and esophagus of at least 10 fish in each age class was pooled. A sub-sample was removed and counted under a dissecting scope to estimate prey composition. The relative contribution of each prey item was estimated by measuring a sample of individuals and converting to weight as with the zooplankton samples. Diet overlap of individual age classes was calculated from niche overlap indices (Keast 1978).

Total food consumption for individual kokanee of each age class was estimated from observed growth in weight of fish in trawl samples. A gross growth efficiency (k = growth/ingestion) for dry weight of 0.3 (Egger et al. 1978) was assumed. Kokanee dry weight was estimated from an emperically determined relationship of length to dry weight as a percent of wet weight. By combining estimates of daily meal with kokanee abundance and age class distribution data from the trawl, we were able to estimate food consumption on an areal basis. Comparison of food consumption with zooplankton standing crop was made to determine the magnitude of cropping.

The spatial associations of kokanee and their zooplankton prey were examined in June and September. In each month, 17 zooplankton samples were collected with a towed Miller plankton sampler while simultaneously recording an echogram as described by Rieman (1979). Echograms were used to estimate total fish density. Trawl data were used to convert these to biomass estimates. Each zooplankton sample was counted and measured. Correlation and regression analyses were used to examine the distributional relationships of predator and prey density and size composition.

FINDINGS

Chlorophyll

Chlorophyll "a" at the northern and central lake stations peaked above 20,ug/l in April, declined to lower mid-summer levels and increased slightly again in the fall. Chlorophyll at the southern station peaked at a much lower level and fluctuated throughout the season (Fig. 2). Summer mean chlorophyll "a" was a 3.8iug/l, 4.5,ug/l and 3.8,ug/l at the north, central and southern stations respectively.

Transparency

Secchi transparency in Coeur d'Alene was low during the spring, increased during summer and declined again in the fall (Fig. 3). Transparency generally mirrored chlorophyll concentrations and was probably influenced primarily by phytoplankton density. Transparency was less at the southern station than either of the others, probably due to a greater influence of suspended inorganic material from the Coeur

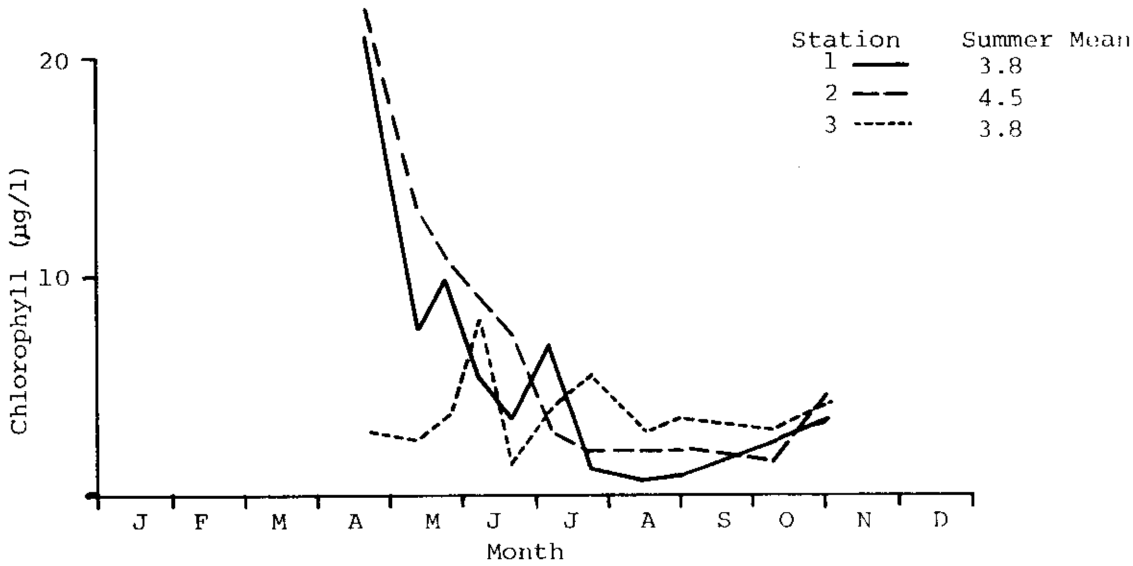

Figure 2. Chlorophyll "a" at three stations in Coeur d'Alene Lake, Idaho 1979.

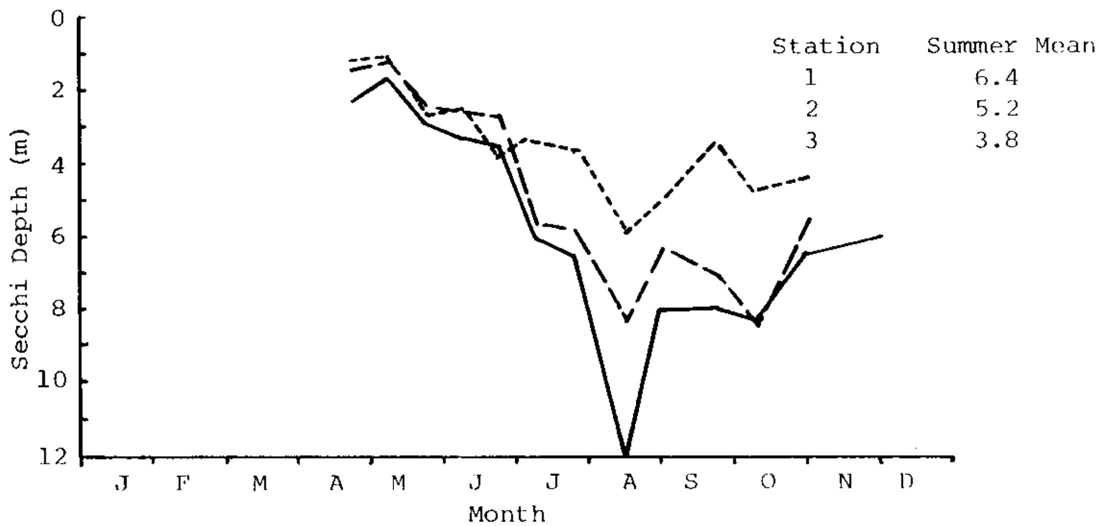

Figure 3. Secchi transparency at three stations in Coeur d'Alene Lake, Idaho 1979.

d'Alene and St. Joe Rivers. Summer mean transparency was 6.4 m at the northern station, 5.2 m at the central station and 3.8 m at the southern station.

Temperature

Coeur d'Alene Lake was obviously warming at the initiation of sampling in April. The lake froze completely during the winter of 1979 (the first time in 10 years) ice broke up during March with mixing occurring during March and April. Stratification was evident by May. Although stratification was never strong, a seasonal thermocline had developed by June and was maintained between 10 m and 15 m (32.8 - 49.2 ft) until early October (Fig. 4). Maximum heat content occurred during August and September.

Initial warming was faster on the north end than the south end of the lake (Fig. 5). Thermal gradients were similar in the upper strata of each end but a more dramatic gradient existed close to the bottom on the shallow south end of the lake.

In comparison with Pend Oreille Lake, Coeur d'Alene warmed and cooled faster (Fig. 6). Maximum heat content in Pend Oreille was slightly higher though summer mean temperature of the upper 15 m (49.2 ft) was less, 12.7 C (55 F) vs 14.5 C (58 F).

Dissolved Oxygen

Dissolved oxygen (D.0.) profiles were collected at four sampling stations on 6 September. Although D.O. was adequate for supporting salmonids, a decline in oxygen with depth was obvious at each station (Table 1). The lowest measured D.O. was 5.9 mg/l just off the bottom at station 3 in the south end of the lake.

Macro-zooplankton

From zooplankton samples collected in Coeur d'Alene Lake during 1979 we recognized three species of copepods, Cyclops bicuspidatus thomasi, Diaptomus sp., Epischura nevadensis, and four species of cladocera, Bosmina lonqirostris, Diaphanasoma leuchtenbergianum, Daphnia sp. and Leptodora kindtii.

Diaphanasoma was a co-dominant numerically with Cyclops and Bosmina but because of its large size it was by far the most important animal in terms of biomass, contributing 61% of the total summer mean (Table 2). Diaphanasoma was present in samples from May through November with maximum abundance during August and September. There was little variation in temporal distribution of Diaphanasoma throughout the lake. Abundance was generally higher in the southern part of the lake than in the north (Fig. 7). Temporal distribution and peak abundance in 1979 also appeared similar to that in 1977 and 1978 (Fig. 8), but the mean summer biomass was less than half of that in 1977 (Table 2).

Bosmina lonqirostris was a numerical dominant (39% summer total) during 1979 but was less important in biomass (5%). Bosmina was present throughout the 1979 sampling and exhibited a major peak in abundance during June and July and a secondary increase in late October (Fig. 7). Abundance varied considerably throughout the lake. Bosmina increased more rapidly and reached much higher densities in Wolf Lodge Bay than in the remaining areas. Abundance of Bosmina was lower than that observed in 1977 and 1978 (Fig. 8, Table 2).

Cyclops was numerically the dominant member of the macro-zooplankton in Coeur d' Alene during 1979 and second in biomass to Diaphanasoma (Table 2). Cyclops was present throughout the 1979 sampling. Densities were low in the spring but increased duringJune. No consistent differences were obvious between different sections of

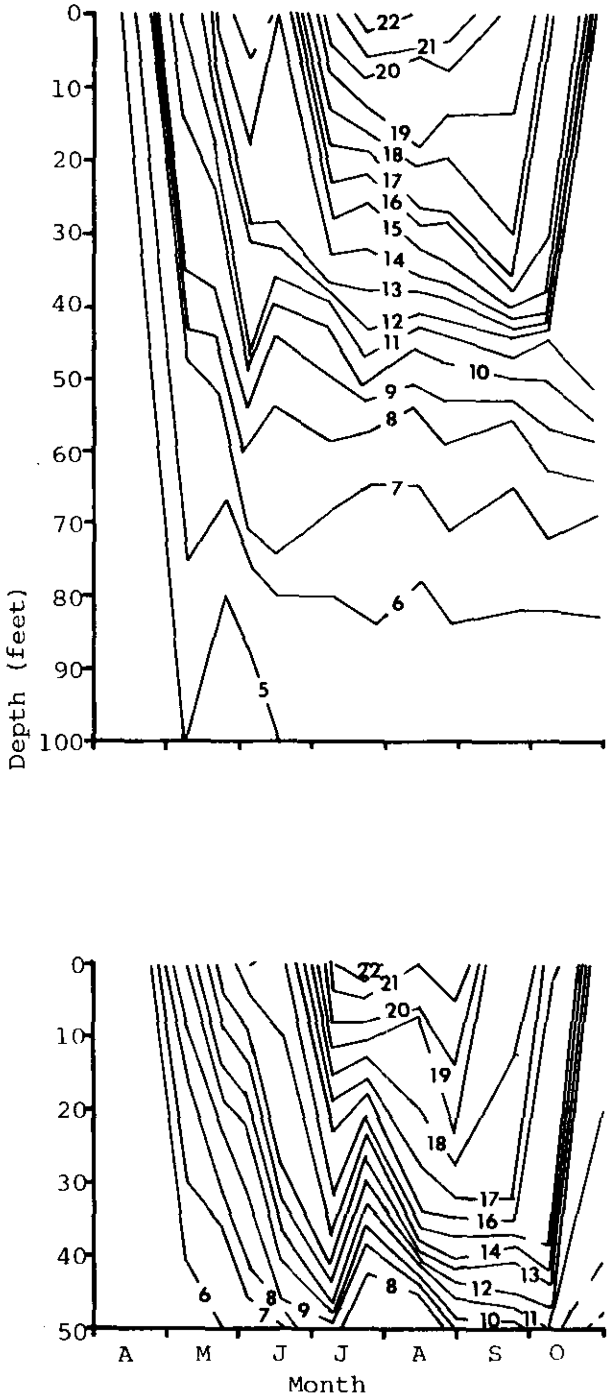

Figure 4. Isotherms at two stations
in Coeur d'Alene Lake, Idaho
1979.

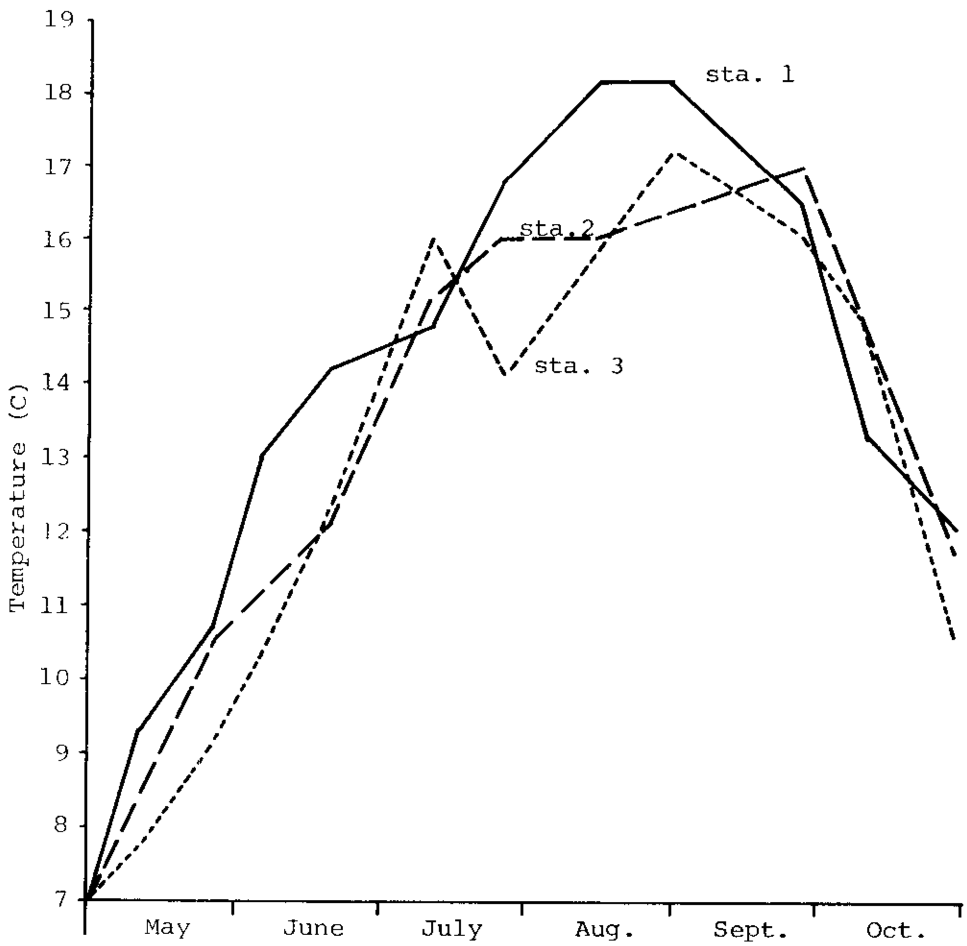

Figure 5. Mean temperature in the upper 15M at three stations on Coeur d'Alene Lake, Idaho 1979.

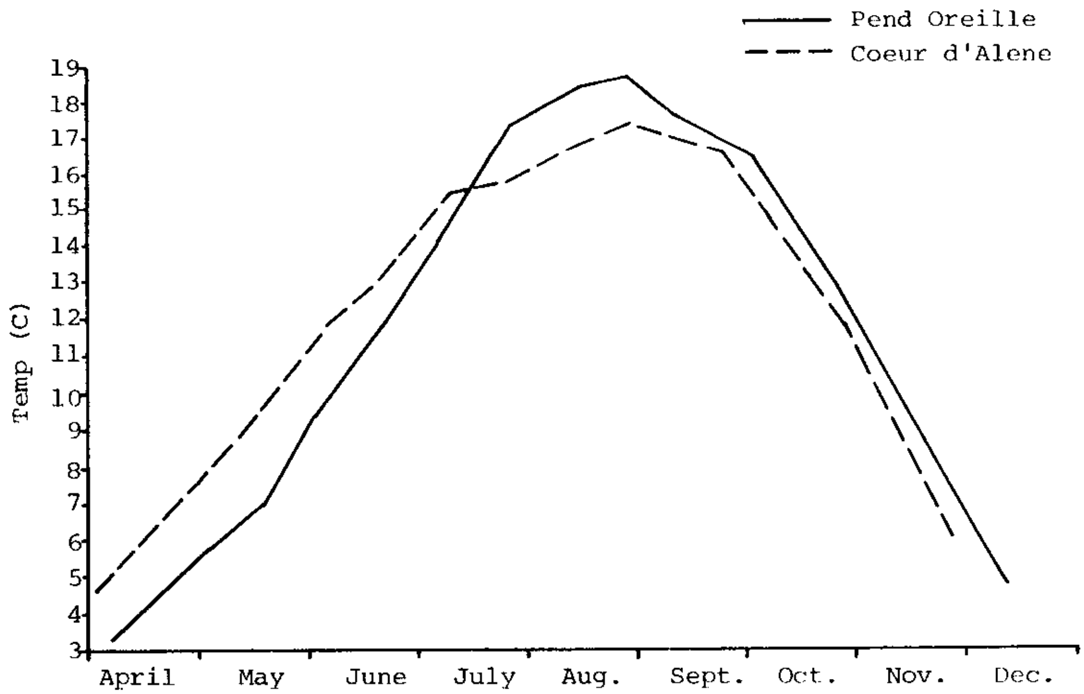

Figure 6. Comparison of mean temperatures in the upper 15m of Pend Oreille Lake and Coeur d'Alene Lake, Idaho 1979.

Table 1. Dissolved oxygen (D.O.) profiles for four stations in Coeur d'Alene Lake on 6 September 1979.

	Wolf Lodge Bay	Station 1	Station 2	Station 3
Depth (m)	D.O. (mg/1)	D.O.	D.O.	D.O.
Surface	11.0	11.0	11.6	11.2
5	--		--	10.0
10	9.8	10.4	10.2	9.4
15	--	--	--	7.2
20	8.0	10.2	9.2	5.9 (bottom)
30	6.5 (bottom 25 m)	9.4	9.6	
40		8.4 (bottom)	8.2 (bottom 39 m)	

Table 2. Summer mean zooplankton biomass and density in Coeur d'Alene Lake, Idaho 1977 and 1979.

Year		Cyclops	Diaptomus	Epischura	Bosmina	Daphnia	Leptodora	Diaphanasoma	Total
1979	mean density (#/1)	4.76	2.02	0.015	4.37	0.04	0.0073	3.44	14.81
	mean biomass (mg/m^3)	5.79	3.66	0.08	1.56	0.17	0.10	17.50	28.78
1977	mean density	10.50	--	--	7.30	--	--	6.07	23.84
	mean biomass	9.0	--	--	3.0	--	--	42.20	54.7

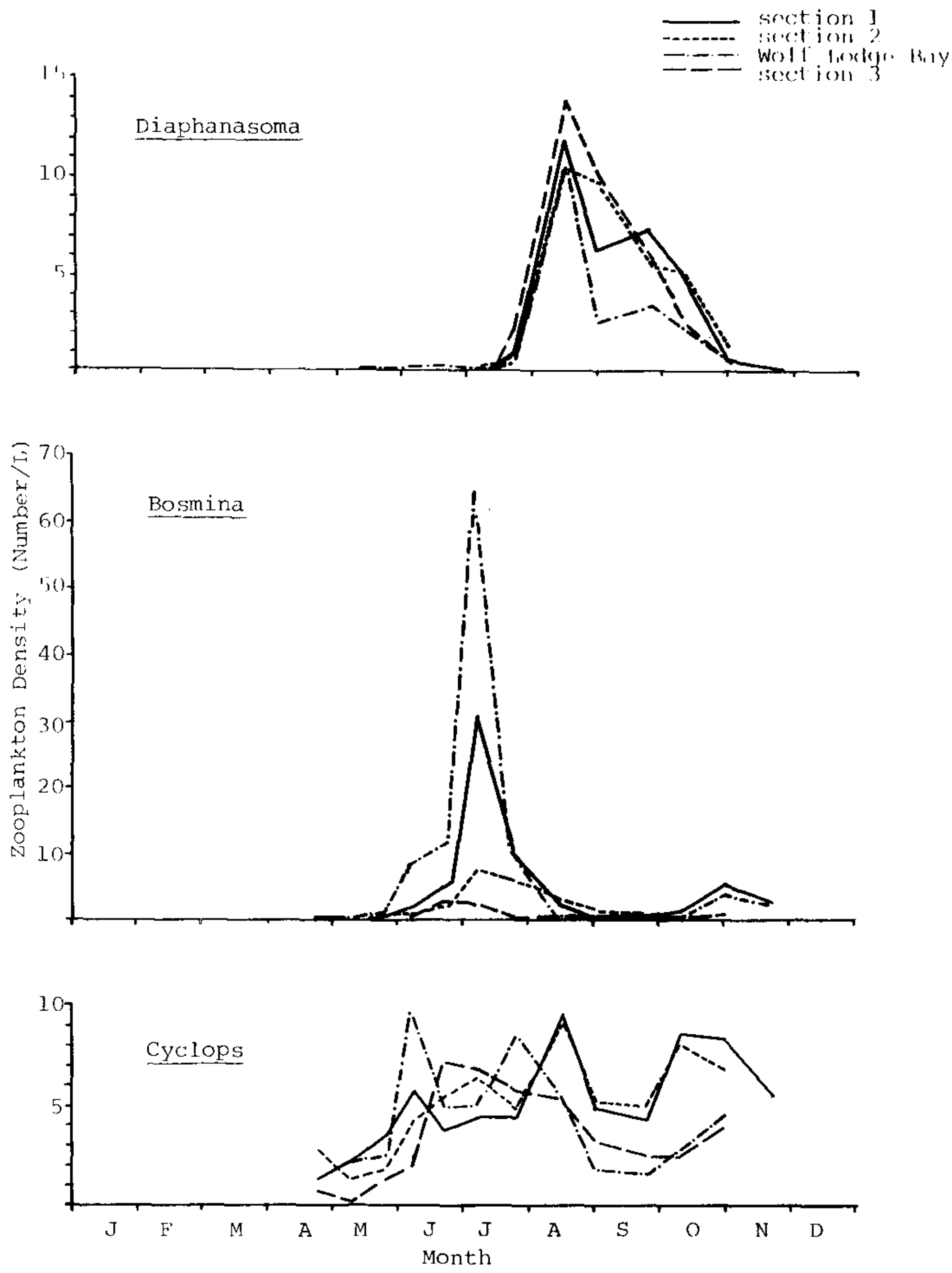

Figure 7. Zooplankton density in three sections and Wolf Lodge Bay in Coeur d'Alene Lake, Idaho 1979.

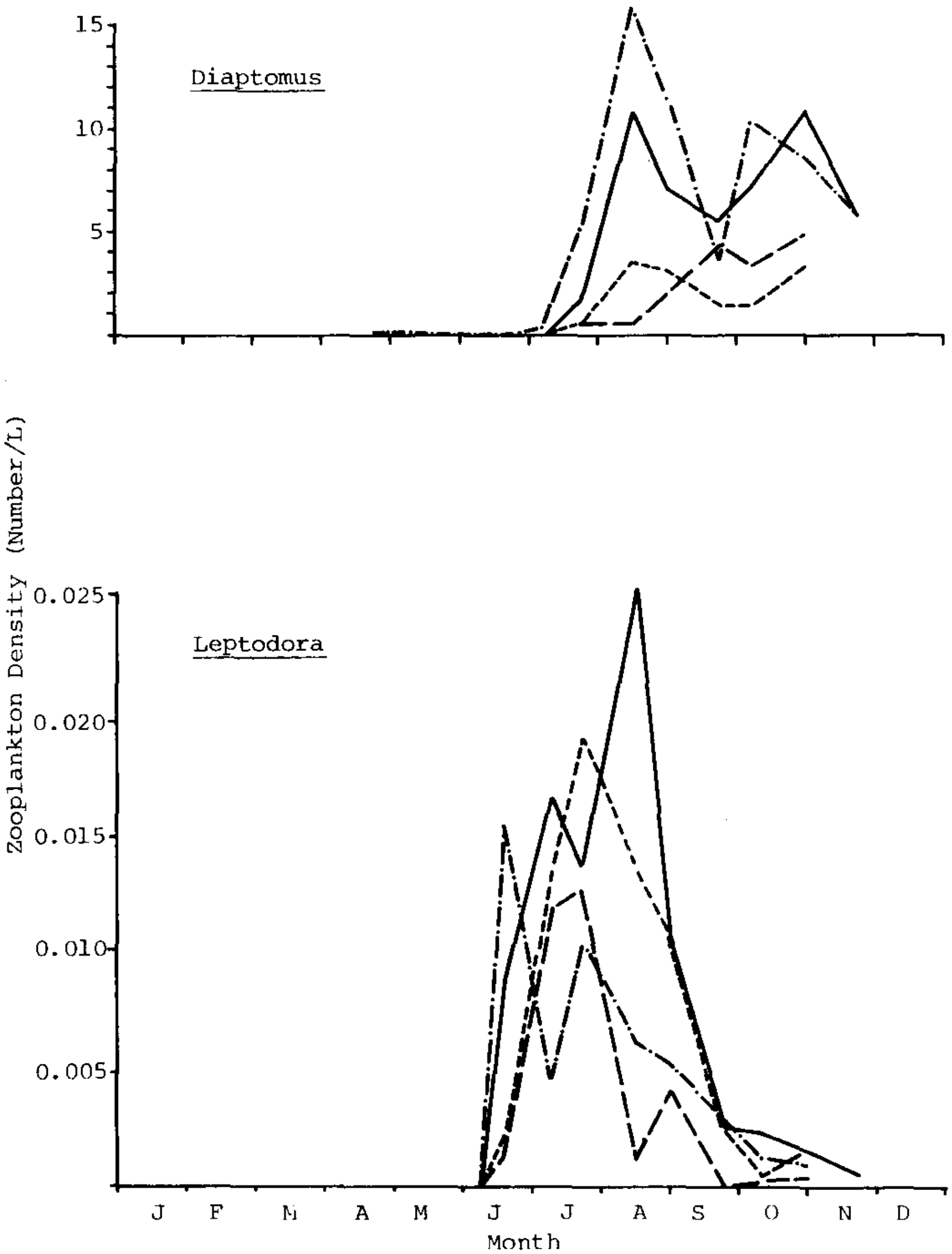

Figure 7. (continued) Zooplankton density in three sections and Wolf Lodge Bay in Coeur d'Alene Lake, Idaho 1979.

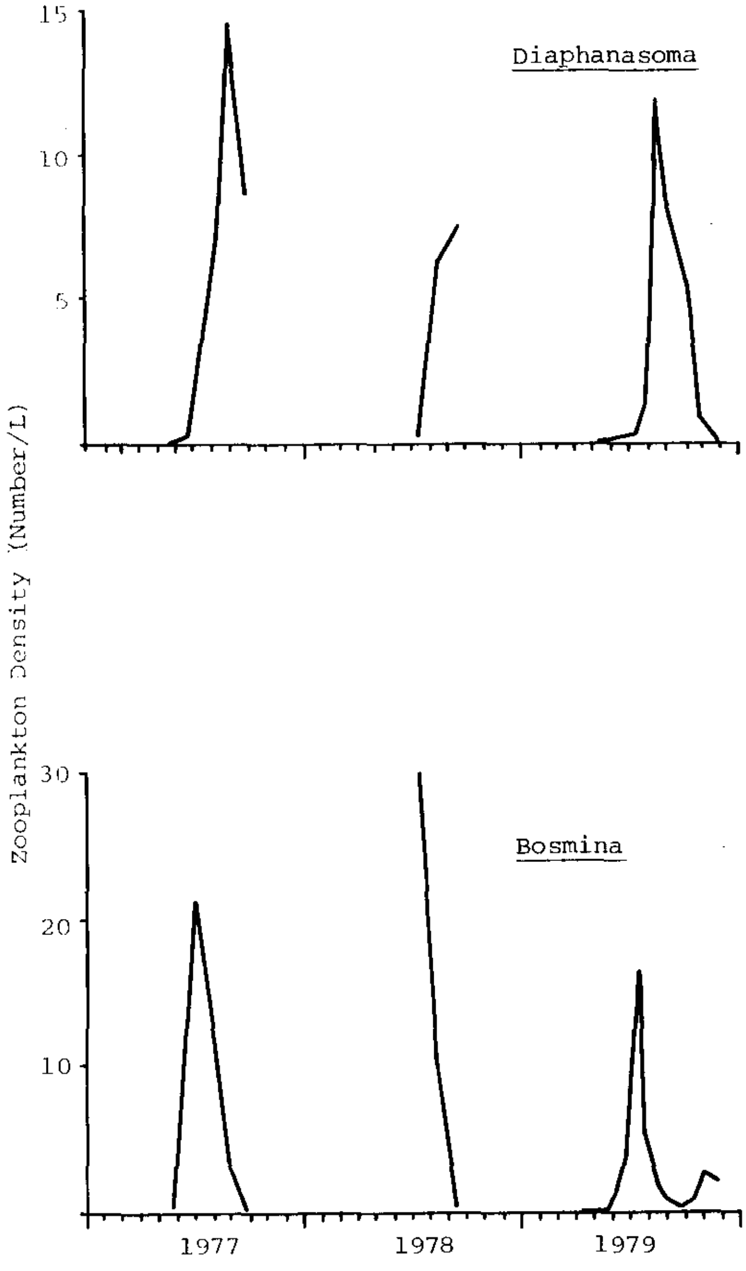

Figure 8. Mean zooplankton density in Coeur d'Alene Lake, Idaho 1977-1979.

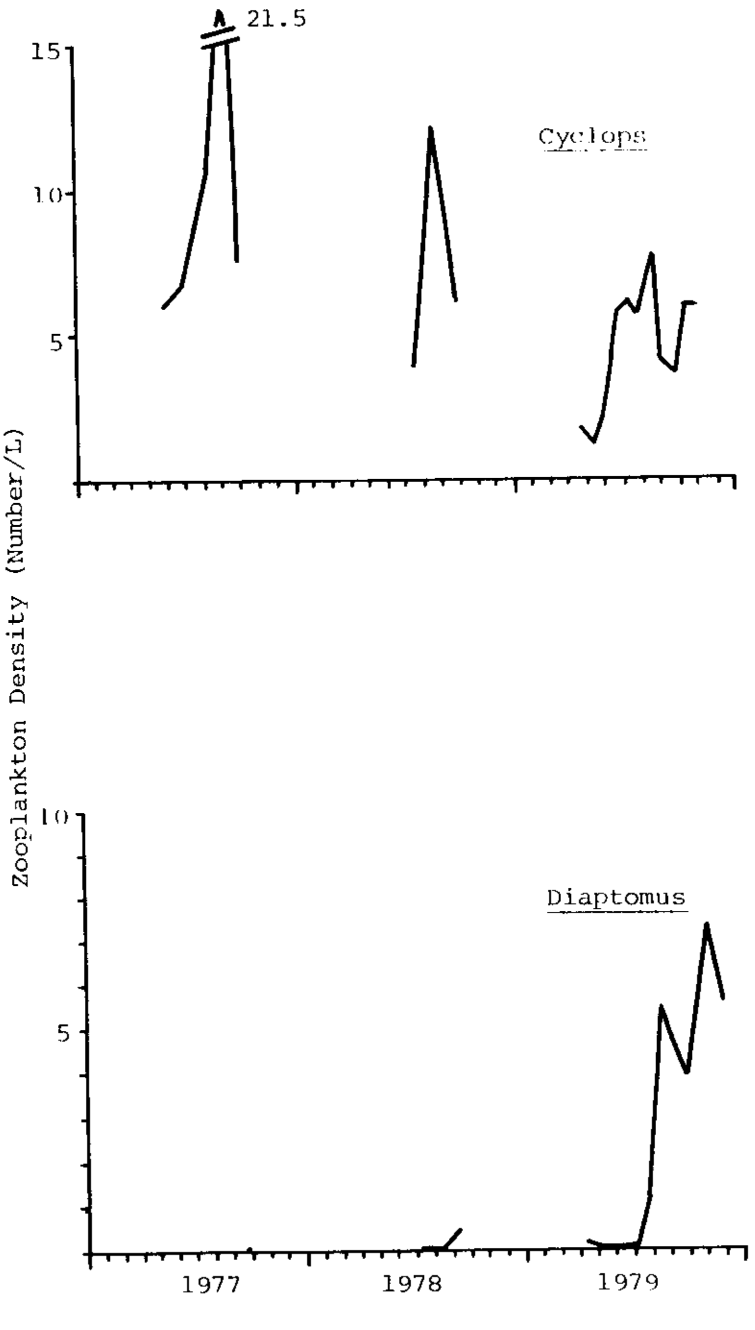

Figure 8.(continued) Mean zooplankton density in Couer d'Alene Lake, Idaho 1977-1979.

the lake. Cyclops was considerably less abundant during 1979 than in 1977 or 1978 (Fig. 8).

Diaptomus increased dramatically in abundance during 1979 relative to the two previous seasons. Diaptomus was a relatively important component of the macro-zooplankton in 1979 (Table 2). The copepode also was much more abundant in Wolf Lodge Bay and the northern sampling area than in the main and southern parts of the lake.

Epischura and Daphnia occurred sporadically in samples throughout the season. Both were relatively insignificant in numbers and biomass (Table 2).

Leptodora was present in plankton samples from June through the end of sampling. Peak abundance occurred during July and August (Fig. 7). Although Leptodora was a relatively insignificant member of the macro-zooplankton in numbers or biomass the densities observed were roughly 16 times those in Pend Oreille Lake.

Total zooplankton biomass increased during June and July with a peak occurring during August. Biomass increased more rapidly and peaked higher in Wolf Lodge Bay than in the other lake sections, but also declined faster in that area in the fall. Summer mean biomass was highest in Wolf Lodge Bay and section 1 (Fig. 9). Total zooplankton biomass in 1979 was approximately half of that observed in 1977 (Table 2, Fig. 10).

Comparison with Priest and Pend Oreille Lakes

The 1979 summer mean biomass of macro-zooplankton in Coeur d'Alene was similar to that observed in Priest and Pend Oreille Lakes. The range in biomass in Coeur d'Alene (28.8 to 54.7 mg/m^3) is also similar to that observed in Pend Oreille. The macro-zooplankton genera in each lake include Cyclops, Diaptomus, Epischura, Daphnia and Bosmina. Diaphanasoma and Leptodora are common to Pend Oreille but were not found in Priest. Though species are similar, relative composition is much different. The large cladoceran Diaphanasoma easily dominates the macro-zooplankton in Coeur d'Alene. Both Daphnia and Diaphanasoma are much less important in Pend Oreille and Priest Lakes.

A comparison of zooplankton abundance in the major fry recruitment areas of Coeur d' Alene (Wolf Lodge Bay) and Pend Oreille (Scenic and Idlewild Bays) Lakes was made to assess differences in early food availability during recruitment. The initial abundance of Bosmina and estimates of total biomass above 10 m (32.8 ft) (from species composition and vertical distribution) was much higher in Coeur d'Alene than Pend Oreille Lake. Total biomass also increased more rapidly in Coeur d'Alene during early June but differences later in the season were negligible. Mean June biomass in Wolf Lodge Bay was 17.7 mg/m^2 compared with 9.7 mg/m^3 in Scenic Bay and Idlewild Bay on Pend Oreille.

The mean lengths of Cyclops, Bosmina and Diaphanasoma throughout the season were compared between Pend Oreille and Coeur d'Alene samples. Mean length and range of length for clops was similar in both lakes though the Pend Oreille animals tended to be larger in the spring and fall (Fig. 11). Both Bosmina and Diaphanasoma were generally larger in the Pend Oreille samples (Figs. 12, 13).

Kokanee Feeding and Trophic Interactions

During 1979 Cyclops, Bosmina and Diaphanasoma were the primary prey items used

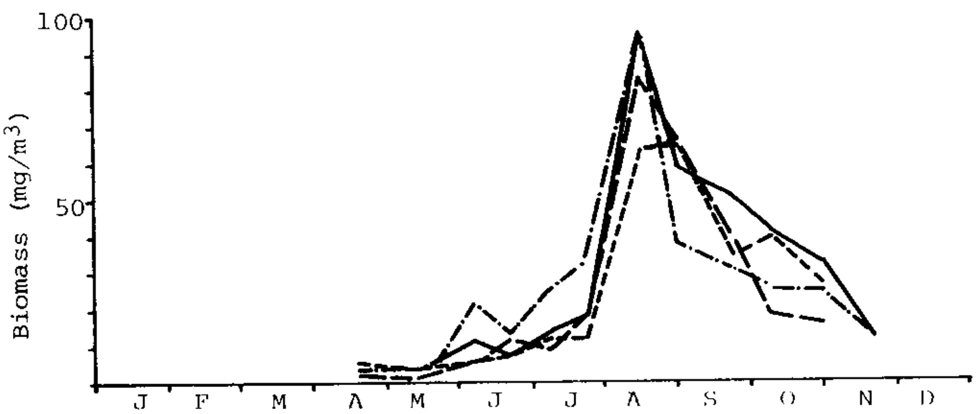

Figure 9. Zooplankton biomass in three sections and Wolf
Lodge Bay in Coeur d'Alene Lake, Idaho 1979.

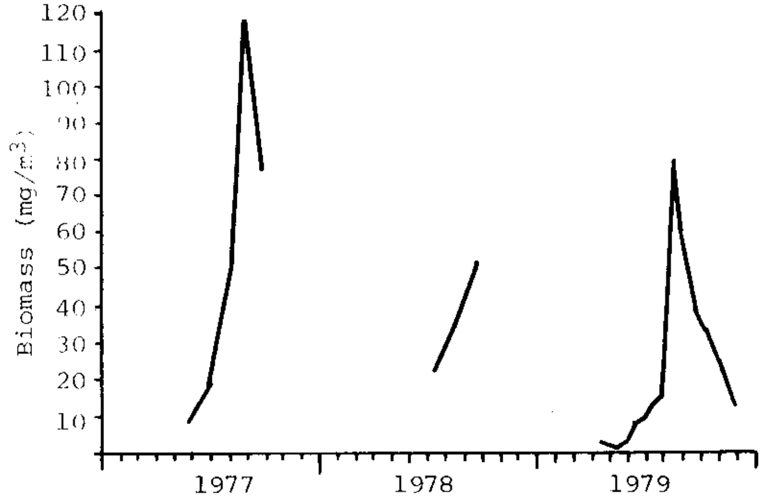

Figure 10. Mean total zooplankton biomass in Coeur d'Alene Lake, Idaho 1977-1979.

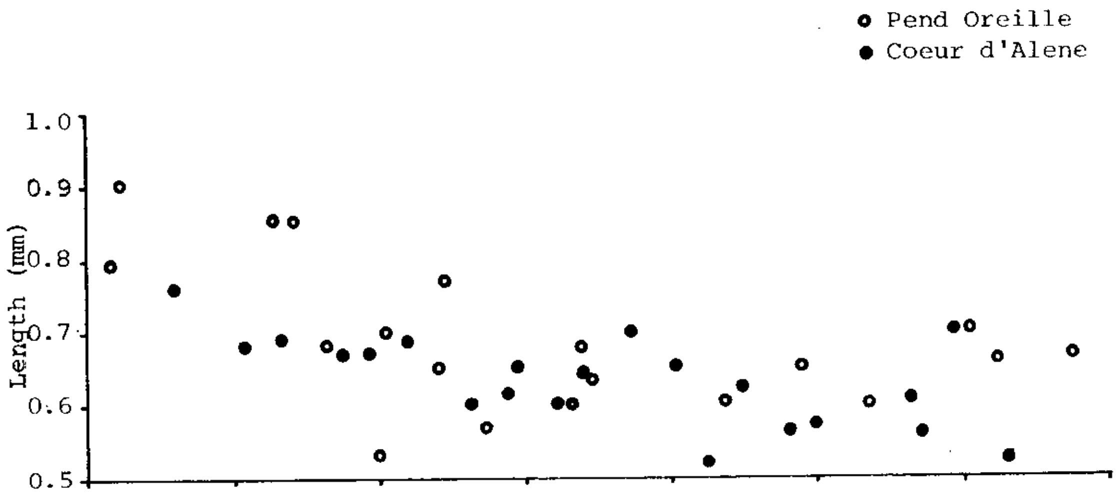

Figure 11. Mean lengths of <u>Cyclops</u> in Pend Oreille and Coeur d'Alene Lakes, Idaho.

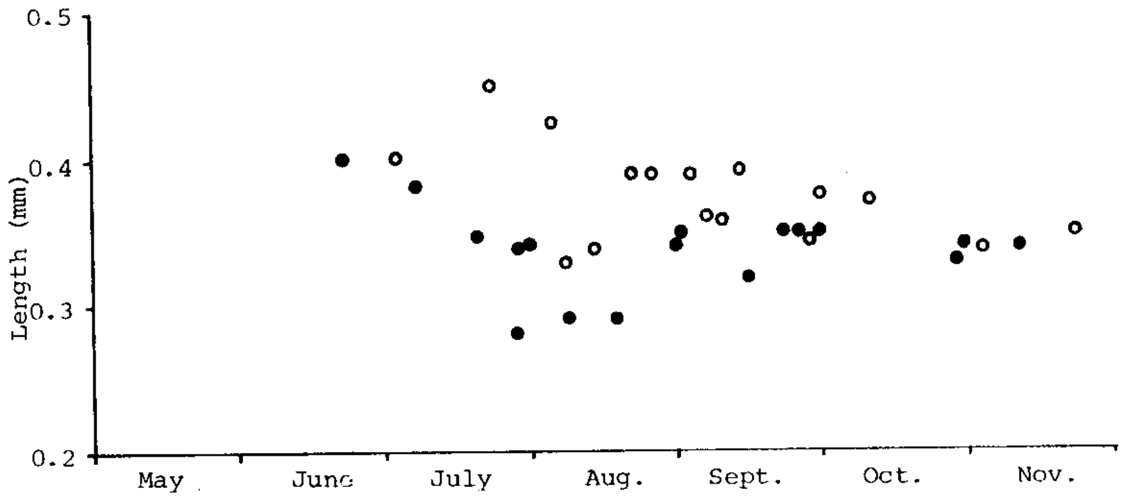

Figure 12. Mean lengths of <u>Bosmina</u> in Pend Oreille and Coeur d'Alene Lakes, Idaho

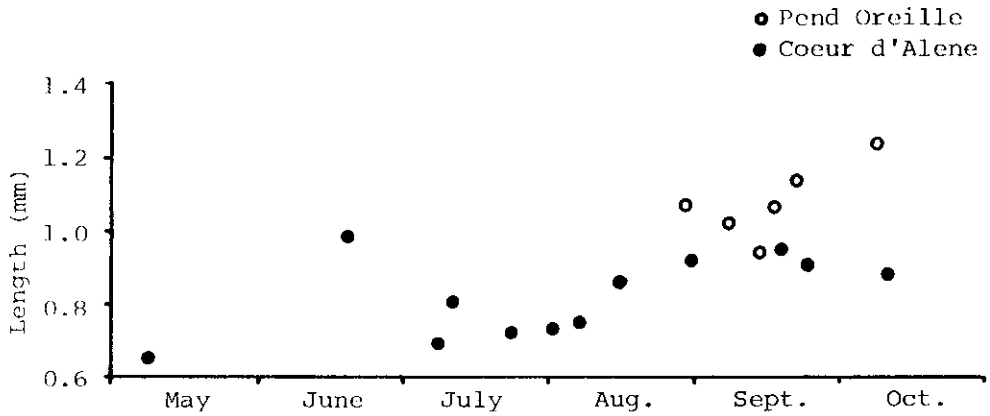

Figure 13. Mean lengths of *Diaphanasoma* in Pend Oreille and Coeur d'Alene Lakes, Idaho.

by kokanee. Cyclops and Bosmina were important during May and June. By August the 1+, 2+ and 3+ age groups fed almost exclusively on Diaphanasoma. Age 0+ fish made higher use of Bosmina during June than did the older age classes. The young-of-the-year also did not use Diaphanasoma extensively until late September (Table 3). Estimates of total food consumption based on growth and food composition show that Diaphanasoma composed the major portion (64.4%) of all food consumed by kokanee during 1979 (Table 4). Cyclops and Bosmina were a much more important part of the total food for age 0+ and even age 1+ fish than for older kokanee. Estimates of diet overlap for the summer were much lower in comparisons with age 0+ fish than any among any of the older fish (Table 5).

Estimates of summer food consumption for individual fish ranged from 0.6 g/age 0+ to 42.6 g/age 3+. The average daily ration ranged form 8.8% body weight/day for age 0+ to 0. 9% for age 2+ (Table 6). We estimate that the rate of food consumption by the population ranged from 1 mg/m^2/day during the May-June period to 12.6 mg/m^2/ day in the July-August period with a summer average of 7.7 mg/m^2/day (Table 7).
Total consumption through the summer was 1,053 mg/m^2.

Estimated cropping of zooplankton (% of biomass lost/day) ranged from 0.5% to 1.2% of total biomass/day, with a summer average of 1.0%/day (Table 8). Estimated cropping of preferred prey was generally higher ranging from 0.3% of Cyclops biomass/day in the May-June period to 3.3% of Diaphanasoma/day during June-July.

The spatial association of kokanee and their prey was examined in June and September. During June significant (p = .05) positive relationships were observed between kokanee biomass and Cyclops biomass and between kokanee density and Cyclops biomass (Fig. 14). Elimination of data from section 5 substantially improved the second relationship. There was no apparent relationship between abundance of kokanee and size of zooplankton used as prey.

In September there was again a significant positive relationship between kokanee biomass and Diaphanasoma biomass (Fig. 15). We found a negative relationship between kokanee density and mean Diaphanasoma length (Fig. 16). Although the correlation coefficient was significant only at p = .10, it does suggest that high densities of fish did result in a reduction in size of the key prey item. The difference in mean length of Diaphanasoma in section 1 (highest kokanee density) and section 5 (lowest kokanee density) was highly significant (p = .01). No relationship was observed between kokanee biomass and Diaphanasoma length.

Calculation of instantaneous growth rates (as % biomass increase/day) for each age class indicates that age 0+ and 1+ kokanee had their highest rate of growth during July. The age 2+ and 3+ fish showed no growth until July with peak growth rate in August (Fig. 17).

Growth rate of age 2+ and 3+ kokanee was significantly (p = .05) and positively related to total zooplankton biomass and Diaphanasoma biomass (Table 9). The x intercepts (growth rate = 0) occurred from 4 to 7 mg/m^3 of Diaphanasoma. Age 0+ and 1+ growth was positively related to Cyclops biomass and Cyclops + Bosmina biomass, though the correlation for age 0 fish was not significant. The x intercept for 1+ fish was from 4 to 5 mg/m^3.

During the period of fry recruitment a number of stomachs collected from age 0 fish were empty. The proportion of empty stomachs appeared to be negatively related to the biomass of the preferred prey item at that time. Similar results were observed

Table 3. Relative stomach composition (% total by weight) of four age classes of kokanee in Coeur d'Alene Lake, Idaho 1979.

Age	Date	Cyclops	Diaptomus	Bosmina	Daphnia	Diaphanasoma	Leptodora	Insects
0+	6/15	46		54				
	6/22	36		64				
	7/24	96		4				
	8/16	94				6		
	9/4							
	9/24	80				20		
	10/22	1	4			95		
1+	5/31	52		28		5		
	6/23	44		50				15
	7/25	81		.05		19		6
	8/16	1				99		
	9/26					100		
	10/22	.06	.02			100		
2+	5/31	69		16				15
	6/23	48	5	31	3	8		6
	7/25	74				23	3	
	8/16	4				96		
	9/26	.6			.2	98	.8	
	10/22	.06	.2			100		
3+	5/31	70		20				10
	6/23	33		13		14		40
	7/25	65		.1		.3	35	
	8/16	1				99		
	9/26					100		
	10/22					100		

Table 4. Estimated[1] proportion of individual prey items of all food consumed by four age classes of kokanee during summer in Coeur d'Alene Lake, Idaho 1979.

Age	Cyclops	Bosmina	Diaphanasoma	Leptodora	Insects
0+	78%	22%			
1+	35%	9%	55%		1%
2+	23%	2%	76%		
3+	19%	2%	76%	3%	
Total	29%	6%	64%	1%	

'From estimates of total food consumption (based on growth), stomach composition, and fish desnities.

Table 5. Mean diet overlap' of four age classes of kokanee in Coeur d'Alene Lake, Idaho 1979.

Age	0+	1+	2+	3+
0		.56	.28	.24
1+	--	--	.97	.84
2+	--	--	--	.99

'Calculated from niche overlap indices (Keast 1978). The higher the value the greater the overlap of feeding. Identical food habits would yield an index of 1.0.

Table 6 . Estimated daily ration (% body weight consumed/day) daily meal (g/fish/day) and total summer consumption (g/fish) for four age classes of kokanee in Coeur d'Alene Lake, Idaho 1979.

Age	Mean daily ration	Mean daily meal	Total summer consumption
0+	8.8%	0.005	0.6
1+	3.5%	0.16	18.6
2+	0.9%	0.12	15.5
3+	1.2%	0.34	42.6

Table 7. Estimated' food consumption (mg/m2/day) by all kokanee in Coeur d'Alene Lake, Idaho 1979.

Age	May_	June	July	Aug.	Sept.	Oct.	Summer mean
0+	0.1	0.2	0.2	0.1	--		.2
1+	0.6	3.9	4.3	4.1	2.6		3.4
2+	0.2	0.2	4.6	3.8	0.3		2.1
3+	0.2	0.2	3.7	3.1	0.7		2.2
Total	1.0	4.5	12.6	11.1	3.6		7.7

'From estimates of individual consumption and fish densities.

Table 8. Estimated cropping of macro-zooplankton by kokanee in Coeur d' Alene Lake, Idaho 1979.

Period	Portion of total zooplankton biomass consumed/day	Portion of preferred prey biomass consumed/day	
May-June	0.5%	(Cyclops)	0.3%
June-July	1.2%	(Bosmina) (Diaphanasoma)	1.4% 3.3%
July-August	0.9%	(Cyclops) (Bosmina)	1.3% 0.9%
August-September	0.6%	(Cyclops) (Diaphanasoma) (Diaphanasoma)	1.8% 0.8% 0.8%
September-October	0.4%,	(Diaphanasoma)	0.7%

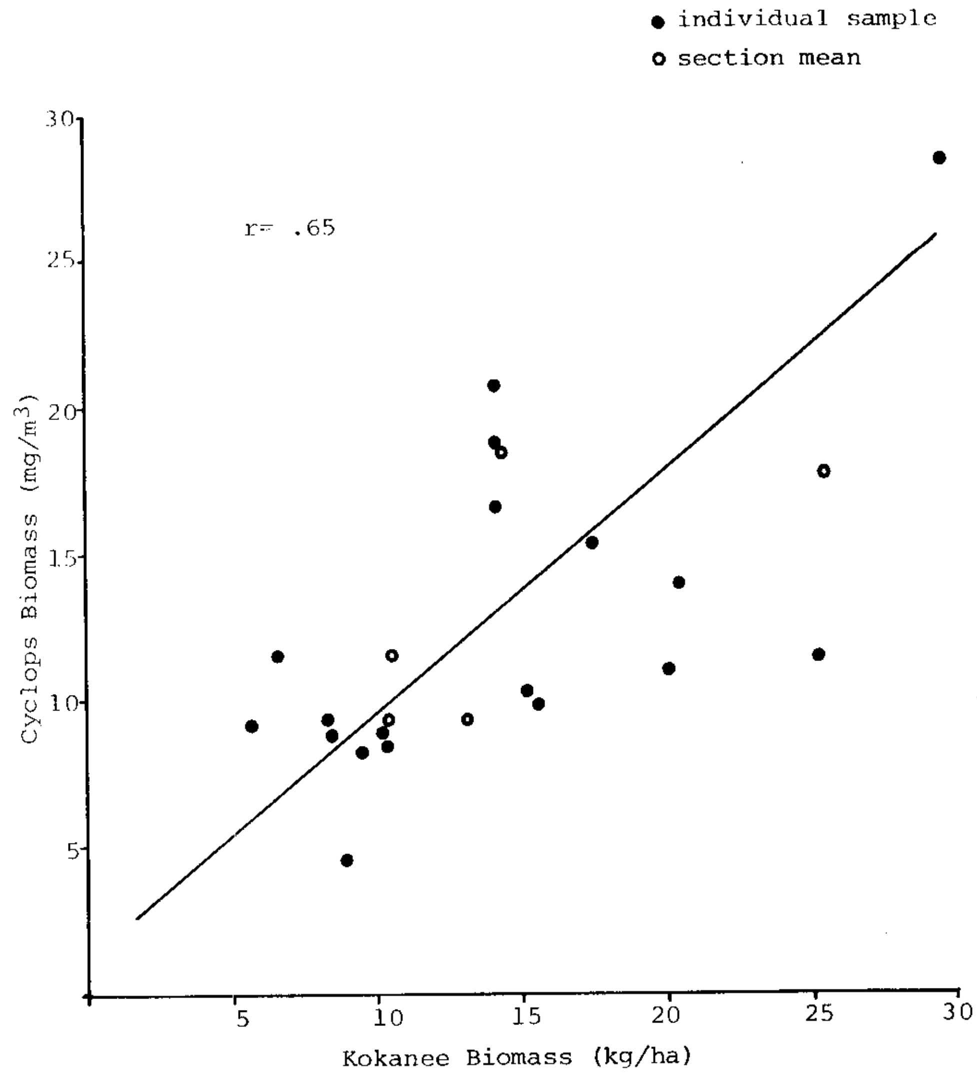

Figure 14. Relationship between kokanee biomass and Cyclops biomass in Coeur d'Alene Lake, Idaho 24 June 1979.

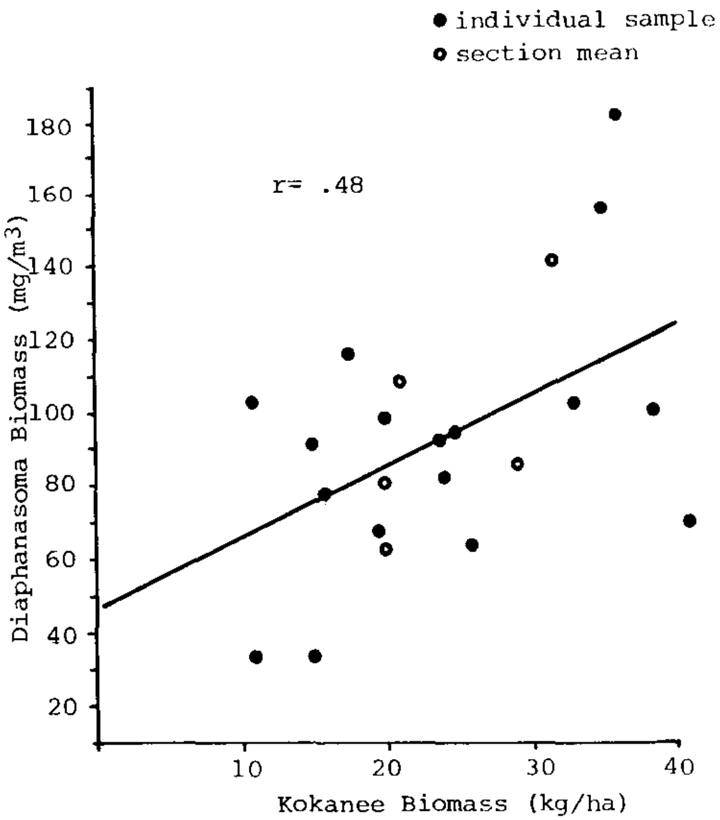

Figure 15. Relationship between kokanee biomass and *Diaphanasoma* biomass in Coeur d'Alene Lake, Idaho 24 September 1979.

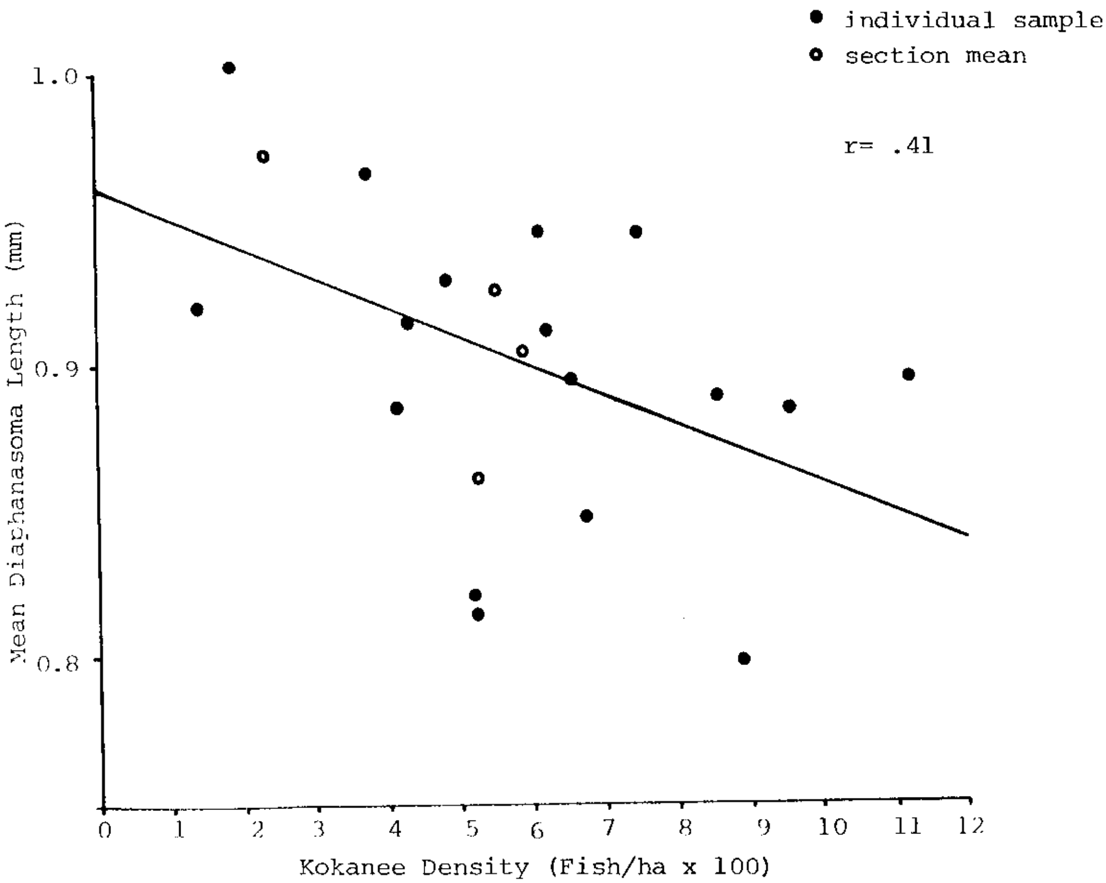

Figure 16. Relationship between kokanee density and mean length of Diaphanasoma in Coeur d'Alene Lake, Idaho on 24 September 1979.

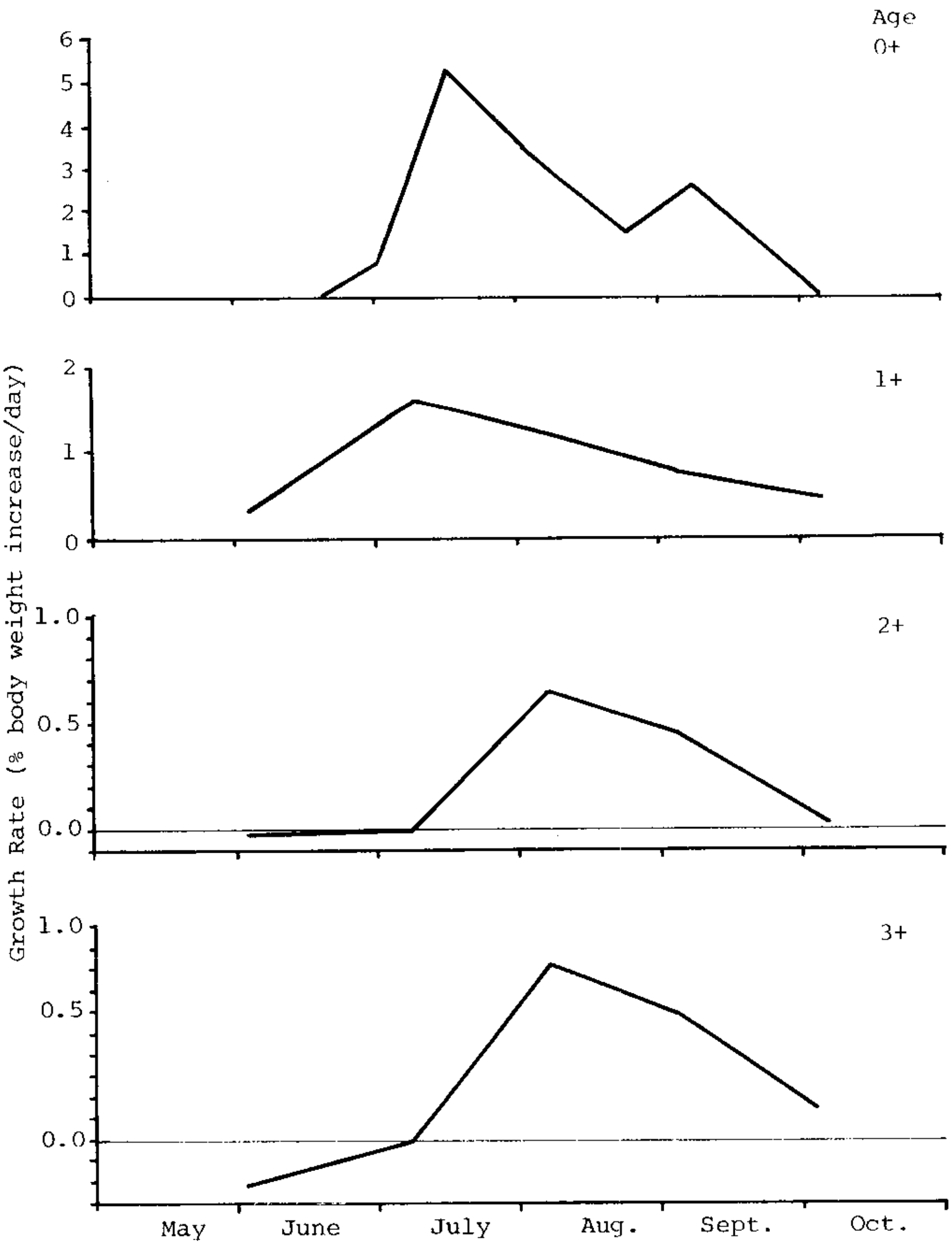

Figure 17. Instantaneous growth rates for four age classes of kokanee on Coeur d'Alene Lake, Idaho 1979.

in Pend Oreille Lake and have been included for comparison (Fig. 18). Because age 0+ fish were using different prey species (Bosmina in Coeur d'Alene, Cyclops in Pend Oreille) and they were distributed differently in the water column, the data has also been presented relating empty stomachs to biomass of preferred prey above 10 m in the water column (Fig. 19). The data indicates that preferred prey abundance must exceed 10 mg/m3 (or ≈,20 mg/m3 above 10 m) before all fry can or will feed effectively.

DISCUSSION

Limnology

On the basis of chlorophyll "a" concentrations Coeur d'Alene Lake would be classified as mesotrophic throughout (Wetzel 1975). Coeur d'Alene is certainly the most productive of the three North Idaho kokanee lakes. The chlorophyll concentrations we observed (0.6 - 22. 2,micro g/l) are similar to those reported by USEPA (M.S. 1976). The classification of trophic state is also supported by the work of several authors (Trial 1977, Parker and Rabe 1978, Funk et al. 1975). The high productivity of Coeur d'Alene Lake is undoubtedly due to high nutrient loading in the system (Trial 1977, USEPA 1976). However, on the basis of total phosphorous concentrations reported for Coeur d'Alene Lake during spring overturn by the EPA, our summer mean chlorophyll was lower than might be expected (Dillon and Rigler 1974). Productivity of Coeur d'Alene may be inhibited by the short retention time, introduced turbidity and weak stratification. Funk et al (1975) and Trial (1977) have also suggested that productivity may be inhibited by excessive zinc concentrations from the Coeur d'Alene River.

Lower spring chlorophyll in the south end of Coeur d'Alene Lake was undoubtedly due to inhibition by turbidity and high dilution during runoff.

The clinograde oxygen profiles observed during September are typical for meso-eutrophic lakes (Hutchinson 1957). Although we did not observe critically low concentrations of dissolved oxygen for salmonids, Minter (1971) did record severe oxygen deficits in the vicinity of our southern station. It is likely that a serious oxygen deficit occurs in this area periodically. Such conditions might be enhanced by low inflow from the rivers and strong thermal stratification. Be-cause the southern portion of Coeur d'Alene Lake is shallow and because kokanee apparently prefer temperatures below 15 C (59 F), usable habitat in the southern area is restricted to a narrow strata along the bottom during stratification. During summer kokanee densities are low in this area. Oxygen conditions similar to that in 1971 would eliminate usable habitat for kokanee in the southern part of the lake (where depths are < 30 m, 32.8 ft). Further eutrophication, increasing the productivity of the lake, will aggravate the frequency and extent of such habitat loss. Funk et al. (1975) also suggested that any increase in the oxygen deficit of Coeur d'Alene might increase the solubilization of heavy metals in the sediments with negative impact to the biota.

Total zooplankton biomass in Coeur D'Alene was similar to what we have observed in both Pend Oreille and Priest Lakes. Biomass was lower, however, than might be expected from the high productivity of Coeur d'Alene Lake. Flushing can have an important influence on zooplankton standing crop (Johnson 1964). The high exchange rate in Coeur d'Alene probably plays an important role in limiting zooplankton production. Though total biomass was similar to the other lakes, there were important

Table 9. Correlation coefficients (r) for instantaneous growth for four age classes of kokanee and biomass of food in Coeur d'Alene Lake, Idaho 1979.

Age	Total biomass	Diaphanasoma	Cyclops	Bosmina	Cyclops + Bosmina
3+	.92*	.85*	.48	.50	-.14
2+	.88*	.79	.53	.48	-.10
1+	.04	-.03	.73	.71	.87*
0+	-.10	-.12	.46	.23	.41

*Significant at p = .05.

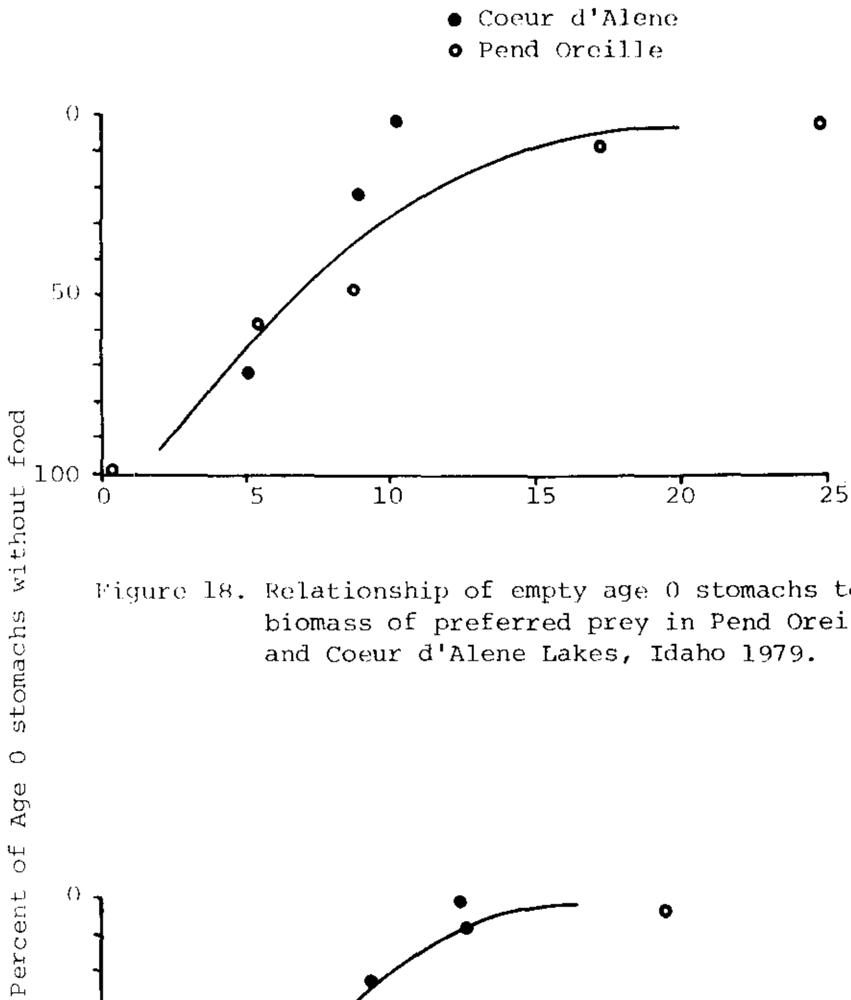

Figure 18. Relationship of empty age 0 stomachs to biomass of preferred prey in Pend Oreille and Coeur d'Alene Lakes, Idaho 1979.

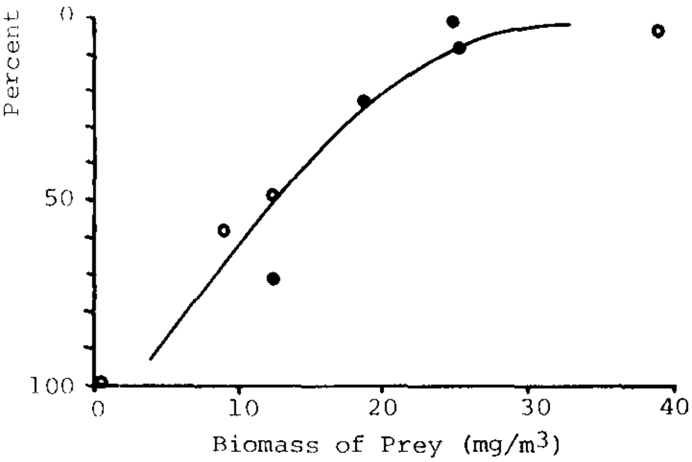

Figure 19. Relationship of empty age 0 stomachs and biomass of preferred prey above 10 m in Pend Oreille and Coeur d'Alene Lakes, Idaho 1979.

differences in zooplankton composition. In Coeur d'Alene the cladocerans Diaphanasoma, Bosmina and Leptodora were much more important than in the other systems. Diaphanasoma alone made up 61% of the summer biomass. The importance of Diaphanasoma may be due to the trophic nature of Coeur d'Alene Lake. Appearance and increase of Diaphanasoma has been associated with eutrophication and increasing productivity of many lakes (Zyblut 1967).

Mysis relicta has also been important in suppressing production of cladocerans in Priest and Pend Oreille Lakes (Rieman 1979a, 1979b) and its absence from Coeur d' Alene is an important difference in these systems. The composition of zooplankton in Coeur d'Alene Lakes is the same as that described by Kemmerer et al. (1923).

There were some important spacial differences in the Coeur d'Alene zooplankton during 1979. Total zooplankton biomass developed more rapidly in the spring in Wolf Lodge Bay than in other parts of the lake. In particular the density of Bosmina increased much more rapidly and reached much higher levels in Wolf Lodge Bay than in the remaining parts of the lake. Such difference may be explained by lake morphometry and the difference in magnitude of flushing and timing during the spring period of zooplankton development. The Wolf Lodge Bay area is essentially isolated from the main lake. Because of the location of the major inlets (the Coeur d'Alene and St. Joe Rivers) and the outlet (Spokane River), probably little main lake water exchanges with the bay. Runoff of the major tributaries to Wolf Lodge occurs earlier in the season (March-April) (Al Issacson Coeur d'Alene Forest personal communication) prior to increasing zooplankton production and is relatively much less than that from Coeur d'Alene and St. Joe Rivers which occurs during the period of initial zooplankton production (May-June). Estimated hydraulic retention is 1,451 days in the Wolf Lodge arm of the lake but only 200 days for the whole lake.

The drainage area of Wolf Lodge Bay is less developed than that of the remaining lake. It is also less influenced by heavy metals. Wolf Lodge Bay serves as the major spawning area on the lake. Regeneration of nutrients from decomposing carcasses has been considered an important nutrient source in sockeye lake systems (Mathieson 1972, Foerster 1968). Crude calculations of the phosphorous potential based on our escapement estimates suggest that phosphorous regeneration in Wolf Lodge Bay from kokanee spawners may be from 0.005 to 0.040 $g/P/m^2$, a potentially significant amount (Wetzel 1975).

Feeding and Trophic Interactions

Coeur d'Alene kokanee food habits were similar to those in Pend Oreille Lake (Rieman 1979a)and other populations (Lindsay and Lewis 1978, Stober et al. 1978). The fish were generally visually selective for the largest and/or most abundant prey items, consistent with optimal prey selection strategy (Werner and Hall 1977). There were some important differences in the food habits of each age class. The importance of Bosmina and Cyclops declined with age and size of fish while the importance of Diaphanasoma increased. Most of the growth of age 0+ fish was associated with the abundance of Bosmina and Cyclops while age 2+ and 3+ growth was apparently dependent upon the availability of the larger Diaphanasoma. The difference in food habits and the low estimates of diet overlap suggest that the trophic interaction of fry and older kokanee in Coeur d'Alene Lake may not be severe. The high density of several important food items (Cyclops, Bosmina and Diaphanasoma) in Coeur d'Alene may provide a good diversity of available food and promote a low level of interaction between age groups.

The relationships of instantaneous growth and feeding with prey abundance indicate that actual *prey* density may have an important influence on growth. More importantly the data suggests that a critical "threshold" density of food exists below which little or no growth occurs. The "threshold" was approximately 4 to 7 mg/m^3 of the predominant p r y item being used by age 1+, 2+ and 3+ fish. It also appeared that 10 to 15 mg/m^i was necessary for most fry to feed effectively. These values might be used as an initial index to the suitability of specific waters to support kokanee and provide for reasonable survival and growth. They might also provide a key to optimize timing of reared fry releases. Further research on fry survival with pen enclosures planned for Pend Oreille Lake will hopefully refine this type of index.

The earlier and higher zooplankton production in Wolf Lodge Bay compared to the rest of the lake is undoubtedly important for the kokanee. Bosmina was a key food item of newly emergent fry. It is generally concentrated near the surface where feeding occurs in June (Rieman 1979) and is likely easier to capture than the copepods W e n n e r et a]. 1978). Adequate densities of such food have been considered. critical to the early survival of sockeye and other fish (Rieman 1979, Rosenthal and Hempel 1970, Cushing 1977, Baegnal and Braum 1971, Braum 1967, Taylor 1980, Foerster 1968, LeBrasseur et al. 1978, Hurley and Brannon 1969). The relation-ship of empty stomachs and Bosmina biomass also shows that the ability of fry to feed may be a direct function of food abundance. It is likely then, that the better availability of zooplankton in Wolf Lodge Bay early in the season has contributed to enhanced survival of fry in that area. We estimated that 76% of all fry production on Coeur d'Alene Lake came from Wolf Lodge Bay during May and June 1979 (Bowler 1980). The predominance of Wolf Lodge Bay as the major spawning and recruitment area may well be linked to its unique limnological characteristics.

We found that food production in Wolf Lodge Bay during the May-June recruitment period was also better than in the major fry producing areas of Pend Oreille Lake. As yet we do not have comparative estimates of fry survival in the two lakes. We did, however, find that initial increase in weight of Coeur d'Alene Lake fry was more rapid than that in Pend Oreille (summer average 2.6% increase in weight/day in Coeur d'Alene vs. 1.4%/day in Pend Oreille). Analysis of scales also indicates that first year growth in Coeur d'Alene has consistently been better than in Pend Oreille (Bowler 1980).

There was also some indication that the eggs from Coeur d'Alene Lake fish were larger than those of Pend Oreille Lake, although size of females in each spawning run was similar. Egg size and quality may be related to quality of the food supply. Larger eggs should result in large emergent *fry* with higher survival. Better food production for mature females in Coeur d'Alene may also enhance fry survival.

Estimated cropping of macro-zooplankton ranged from 0.4% to 1.2% of biomass/day during summer. Cropping of preferred prey was higher, ranging near 3.3% of Diaphanasoma biomass/day. These rates are roughly twice that observed in Pend Oreille Lake (Rieman 1979) but still would appear insignificant as a loss to the zooplankton community and individual populations (Hall 1964, Noble 1975, Northcote et al. 1979, Rieman 1979).

We also examined the predator prey interactions by examining the spatial associations of fish and key prey items. The positive correlations of fish density and prey density are consistent with what we found in Pend Orielle Lake. It is probably explained by fish actively seeking areas of high food availability (Rieman 1979a). Ware (1971) and Slaney and Northcote (1974) found aggregations of trout with high food densities in laboratory systems. We found an apparent negative relationship between kokanee density and mean size of Diaphanasoma during September. Cyclops, Bosmina and Diaphanasoma, the major prey species in Coeur d'Alene, were also consistently smaller than those in Pend Oreille. Kokanee are size selective in their feeding, generally using the largest available prey. Similarly a number of authors have reported changes in the size composition of zooplankton communities with establishment of planktivorous fish populations (Northcote and Clarotto 1975, Brooks 1978, Galbraith 1967). Although the data is far from conclusive it does suggest that the density of kokanee in Coeur d'Alene Lake had some effect on the prey base even though estimated cropping appears to be small. The population in Coeur d'Alene may be approaching the carrying capacity of the system as dictated by food production.

The data from Coeur d'Alene Lake supports the hypothesis of density dependent interactions for kokanee that we developed from data on Pend Oreille Lake (Rieman 1979). The Coeur d'Alene fish grew rapidly when first introduced to the system but declined to their present size (age 3+ spawner, 240-270 mm, 9.4-10.6 in) as the population became established. The fishery had continued to increase in recent years while size has remained relatively stable. The data indicates a density dependent curve for adult fish similar to Figure 20. The initial decline in growth is likely related to competition among fish within a school (Rieman 1979, Eggers 1976). As schools reach an optimum size that effect will cease to increase and total numbers of fish in the lake may fluctuate with no compensatory change in growth, until densities (and new schools) are large enough that the food supply it-self is effected. The density of kokanee in Coeur d'Alene may have been approaching that limit.

The response of age 0+ kokanee may be somewhat different. Age 0+ fish tended to use different food items than the older fish. Segregation probably also occurs spatially with the smaller, slower swimming fry occupying separate schools. If most of the interaction occurs within the schools and the population is not at a high enough density to affect the food supply, there is probably little interaction between schools. Growth of age 0+ fish in Coeur d' Alene was excellent in 1979. Scale indices and measured growth of fry was considerably better than that in Pend Oreille, though growth of older kokanee was similar between the two lakes. Direct competition between fry and older kokanee is probably minimal.

Compensatory pressures that are obviously effecting older fish at present densities probably play little role in the growth and survival of age 0+ kokanee until the fry reach extremely high densities (perhaps densities similar to those of sockeye systems). It is likely that the density dependent response for fry may look different (Fig. 20). Similar conclusions have been suggested from sockeye data collected by IPSFC (Jim Woodley personal communication, Terry Gjernes communication at Pacific Fisheries Biologists' Conference April 1977). Any decline in productivity of the population (fry production) is probably more closely controlled by declining fecundity and egg quality of spawners as a function of the density dependent response described in Figure 18, rather than a compensatory decline in survival of fry.

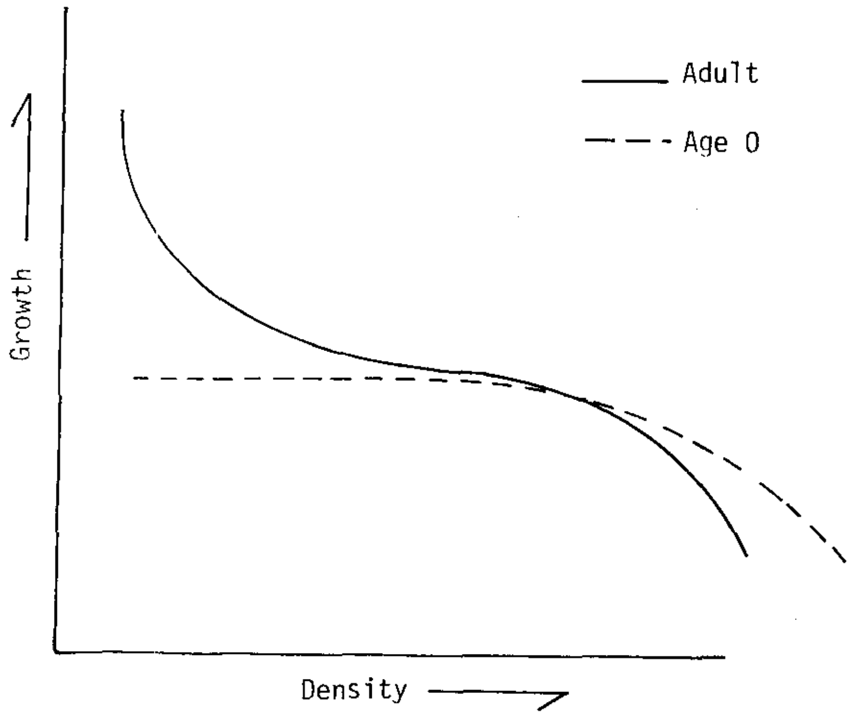

Figure 20. Theoretical density dependent response in growth of adult and age 0 kokanee.

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JOB PERFORMANCE REPORT

State of Idaho

Name: LAKE AND RESERVOIR INVESTIGATIONS

Project No. F-73-R-2

Title: Kokanee Life History Studies in Coeur d'Alene Lake

Study No. V

Job No.

Period Covered: 1 March 1979 to 29 February 1980

ABSTRACT

We used echosounding and mid-water trawling techniques to assess the status of the kokanee stock in Coeur d'Alene Lake during 1979. We measured abundance, assessed distribution of recruitment, monitored growth and estimated year-class strength of the kokanee stock in the lake.

We estimated in September that Coeur d'Alene Lake supported 6,039,964 kokanee (626/ha; 253 acre). The equivalent biomass measured 26.3 kg/ha (23.4 lb/acre).

Young-of-the-year kokanee were mostly recruited in Wolf Lodge Bay where most of the spawning was observed.

Growth to the first annulus from the 1976 and 1977 kokanee year-classes was very comparable suggesting similar survival for the two year-classes.

Estimates of year-class strength for the 1976, 1977 and 1978 kokanee year-classes indicate that fishing success should improve during 1980 and 1981 with success in 1982 being comparable to 1979.

Coeur d'Alene Lake supported a high yield of self-sustaining kokanee fishery during 1979 that should be maintainable. Exploitation may be the most limiting factor to recruitment in the lake but it can be regulated to help maintain population stability.

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RECOMMENDATIONS

Consider the option of managing Coeur d'Alene Lake as a high yield kokanee fishery. Because of its location, accessibility and size the lake presently provides excellent kokanee fishing for a diversity of anglers next to populated areas. The lake does not support a major predator specie and its food base has not been altered by M ysis relicta as have other North Idaho lakes which have declining kokanee populations. Kokanee have been very successful at reproducing in Wolf Lodge Bay, contributing to a self-sustaining population. Further years of data will be necessary to describe the yield per recruit relationship to optimize angler returns. Exploitation may be the most limiting factor to recruitment in the lake but it can be regulated to help maintain population stability.

OBJECTIVES

To assess densities and abundance of the kokanee population in Coeur d'Alene Lake by area and age class.

To assess distribution of young-of-the-year kokanee as an indicator of shore-line spawning areas in the lake.

To make estimates of year-class strength and assess age class composition of the Coeur d'Alene Lake kokanee population.

To measure kokanee growth rates by year-class and compare rates of growth with scales previously collected on the lake.

To assess the age structure of the kokanee spawning population in Coeur d' Alene Lake.

TECHNIQUES USED

We measured relative densities and assessed total kokanee abundance in Coeur d' Alene Lake during 1979 using echosounding. We used a Ross Fineline 200 A depth sounder (105 KHz) with a hull mounted transducer (22° beam angle) fixed in a 6.4-m (21-ft) fiberglass boat (Bowler 1975).

Echosounding for fish abundance measurements was done at night and during the dark phase of the moon for better interpretability of the echograms (Bowler 1975).

For sampling purposes, we stratified Coeur d'Alene Lake into three sections. Each lake section was further divided into 804.9 m (0.5 mi) grids or transects (Fig. 1).

During Septemher of 1979 approximately 25%, of the possible transects in each lake section were selected at random for echosounding which totaled 54 transects for the survey of the entire lake. We traversed through the transects using known boat speeds, compass headings and fixed landmarks. The average boat speed measured 2.4 m/sec (5.5 mph) for echosounding each transect.

The total fish estimates were made by calculating the mean number of fish per transect *from* the echograms found in the volume of water sampled with the transducer cone at 5-fathom (30-ft) intervals and expanding that value to the total volume of water sampled with the transducer cone at 5-fathom (30-ft) intervals and expanding that value to the total volume of water in the lake to the depth at which kokanee were recorded on the echograms. The vertical distribution of kokanee was determined from mid-water trawling. The actual cone volume was computed from the 22° beam angle as the volume of the trapezoid (Bowler 1975). No estimates were made above the 2-fathom (12-ft) level.

The echosounding system used on Coeur d'Alene Lake was the same used on Pend Oreille Lake. It was compared with a calibrated system in 1975 and resultant correction factors were applied to the quantitative estimates for improved accuracy (Bowler 1975). A gain setting of 7 was used on the recorder which allowed for the best resolution of fish targets found in the depth range at which kokanee were distributed, 0 to 46 m (0 to 150 ft).

Trawling

We used mid-water trawling techniques as described by Lewis (1974) for sampling fish species in Coeur d'Alene Lake during 1979. We collected species and age composition information as well as scales, stomachs, length and weight data from the kokanee sampled. We also made estimates of kokanee abundance and year-class strength.

We used an 8.5 m (28-ft) trawling boat equipped with a 140-hp diesel engine, hydraulic winches, a Ross Fineline 200 A depth sounder and two hull mounted transducers (22° and 8° beam angles) (Bowler 1978). The trawl system utilized hydro-dynamic otterboards, depressors and hydrofoils. The net measured 3.05 m (10 ft) square at the mouth and 13.7 m (45 ft) long and contained mesh sizes (stretched measure) graduated from 32, 25, 19 and 13 mm (1-1/4, 1, 3/4 and 1/2 in) in the body to 6 mm (1/4 in) in the codend. Towing speed of the net measured 1.5 mps (4.9 fps). Towing depth was estimated from angle-length relationships and was verified using a time-depth recorder.

All trawling was done at night during the dark phase of the moon to increase capture efficiency. For making quantitative estimates of kokanee we made oblique tows through the vertical distribution of fish targets as observed from the echograms in 3.7-m (12-ft) intervals. The distance traveled and volume sampled in a standard 3.5-minute haul was 305 m and 2,832 m^3 (334 yd, 3703 yd^3), respectively. During September we trawled 18 randomly selected transects throughout the lake with an average of four oblique tows depending on the vertical distribution of fish. This equaled approximately 72 tows. We also made random trawl hauls from early May to late August in Coeur d'Alene Lake to obtain kokanee samples.

We weighed and measured all kokanee and collected scale and stomach samples of the representative age classes. All kokanee fry were preserved in 95% ETOH. Lengths and weights of preserved fry were determined in the laboratory and adjusted to live values using correction factors (0.00 x preserved length and 1.705 x preserved weight).

Age and Growth

We analyzed scales from age $^{1+}$ kokanee collected during 1978 and 1979 in Coeur d' Alene Lake. We made growth rate comparisons by measuring the distance and also enumerating the numbers of circuli to the first annulus. Scales were cleaned and mounted dry between glass slides and analyzed on a microprojector with 41.6 x magnification.

FINDINGS

Fish Abundance

We made an acoustic estimate of fish abundance in Coeur d'Alene Lake in September of 1979. We found from Pend Oreille Lake that the most accurate quantitative estimates are made in late summer and early fall because of reduced sampling variance due to the horizontal and vertical distribution of kokanee at that time (Bowler 1975, 1976). The fish targets counted from the echograms were only those found in the depth range at which kokanee were collected by mid-water trawl. The total acoustic estimate equalled 4, 207,909 fish (436/ha; 183/acre). The section breakdowns are listed in Table 1.

Species Composition

Kokanee made up 99.4% of the 833 fish collected in pelagic trawl hauls during September 1979 in Coeur d'Alene Lake. The remaining 0.6% were 3 suckers and 2 cutthroat trout all ranging in length from 24 to 41 cm (9.4 to 16.1 in).

Kokanee Year-Class Strength

We used a mid-water trawl to make kokanee year-class estimates during September 1979 in Coeur d'Alene Lake. The total trawl estimate equalled 6,039,964 kokanee (626/ha; 263/acre) which was 1.8 million more fish than the acoustic estimate (Table 1).

The strength of the 1978 kokanee year-class (age 0+) in Coeur d'Alene Lake was measured at 1,500,670 fish while the 1977 (age 1+), 1976 (age 2+) and 1975 (age 3+) year-classes were estimated at 2,285,989, 1,792,187 and 461,118, respectively (Table 2) .

Kokanee Distribution

We found kokanee distributed throughout Coeur d'Alene Lake. They were most dense in the central part of the lake (lake section 2) during September 1979 and least dense in the southern part of the lake (lake section 3).

With periodic trawl hauls throughout the lake during the summer of 1979 it was obvious that most of the fry recruitment was occurring in lake section 1. Bimonthly sampling from May to August in lake section 1 also indicated that most of the emergence was coming to the lake from the east end of Wolf Lodge Bay extending westerly approximately to Moscow Bay. Seventy-six percent of the fall fry were found in lake section 1 (Table 2). Other trawl data would suggest there is a southerly movement of kokanee fry beginning in late summer and early fall.

Potential Escapement

We made an estimate of potential kokanee escapement in Coeur d'Alene Lake by assessing the number of mature fish collected in the trawl in September. We found that those kokanee exceeding 220 m (8.7 in) were mature in September and would potentially spawn in November and December. We estimated the lake supported approximately 460, 000 mature kokanee in the fall. Using a 50% female ratio and 375 eggs/female fecundity rate the potential egg deposition was estimated at 86,250,000 for 1979.

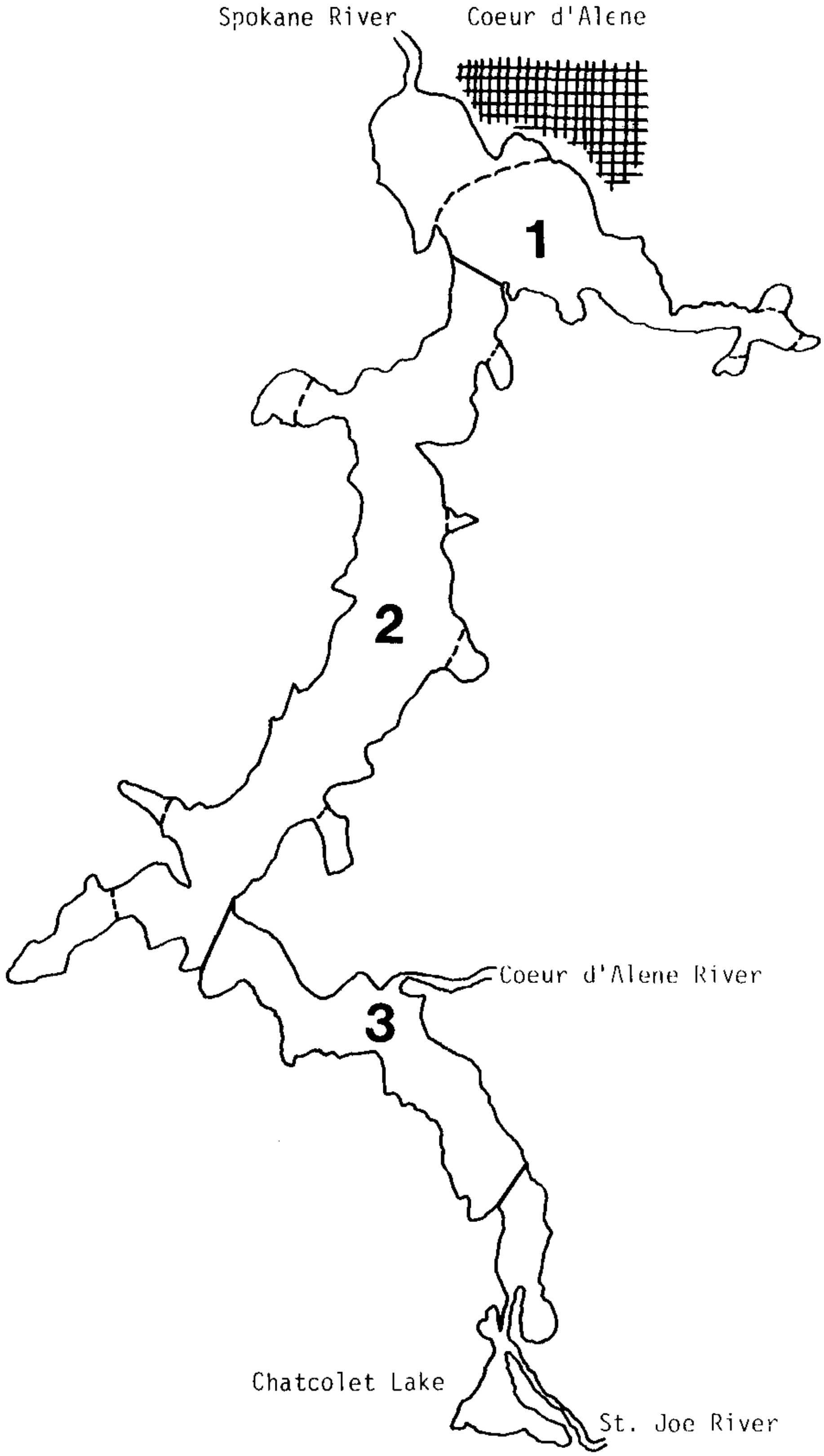

Figure 1. Coeur d'Alene Lake, Idaho with acoustic and mid-water trawling areas used during 1979. Dotted lines represent trawl sampling areas within lake sections. Total area sampled measured 9,647. 75 ha (23,839.26 acres).

Table 1. Acoustic and mid-water trawl estimates of kokanee made in Coeur d' Alene Lake during September 1979 by lake section.

Lake section	Trawl estimate	Acoustic estimate
1	2,241, 172	1,371,794
2	3,653,807	2,552,898
3	144,985	283,217
Total	6,039,964	4,207,909

Table 2. Mid-water trawl estimates of kokanee year-class strength (by lake Section) Liken in Coeur d'Alene lake during September 1979.

Lake section	A e	Estimate	Total
	0+	1,140,596	
2	0+	351,789	1,500,670
3	0+	3,285	
	1+	773,738	
2	1+	1,479,112	2,285,989
	1+	33,139	
1	2+	246,796	
2	2+	1,479,112	1,792,187
3	2+	66,279	
	3+	80,042	
2	3+	343,794	461,118
3	3+	37,282	

Kokanee Biomass

We measured kokanee biomass in Coeur d'Alene Lake in September 1979 at 253,453 kg (558,864 lb) which is equivalent to 26.3 kg/ha (23.4 lb/acre) for the lake (Table 3).

Growth

We physically measured kokanee growth in Coeur d'Alene Lake from May through October. Age 0+, 2+ and 3+ fish gained the most weight between August and October while the age 1+ kokanee began adding weight in July and continued through October (Table 4, Figs. 2, 3). Instantaneous summer growth rates for each age class are listed in Table 4. Also a length frequency for the kokanee sampled in September is described in Figure 4.

We measured the distance and enumerated the number of circuli to the first annulus on age 1+ kokanee collected in Coeur d'Alene Lake during 1978 and 1979. Previous scale collections were limited from the lake. We found a sample of 18 kokanee scales collected in 1960. Because of back calculating bias (Bowler 1979a) we could not adequately compare growth to the first annulus using the 1960 collection. Growth to the first annulus is used as an indicator of first year survival in the lake (Bowler 1979a).

Growth to the first annulus was similar for both the 1976 and 1977 kokanee year-classes. The mean distance to the first annulus measured 17.4 mm (41.6 x) for the 1976 year-class and 16.0 mm (41.6 x) for the 1977 year-class with similar circuli counts (Table 5).

Length and Age at Maturity

Lengths of spawning age kokanee have been collected on Coeur d'Alene Lake from 1954 to 1979. They ranged in length from 409 mm (16.1 in) in 1954 to 245 mm (9.6 in) in 1979 (Table 6, Figs. 5).

We aged 103 kokanee spawners from Wolf Lodge Bay during 1979 with otolith samples. Twenty-two percent were age 2+, 76% were age 3+ and 2% were age 4+. There was considerable overlaps in the lengths of all 3 ages ranging from 225 to 280 mm (8.9 to 11.0 in) (Fig. 6).

Kokanee Releases into Coeur d'Alene Lake

Kokanee were first introduced into Coeur d'Alene Lake in 1937 and have been released almost yearly up through 1977 (Table 7). Almost all of the releases were of the late spawning variety originating from Pend Oreille Lake. From 1970 through 1975 approximately 3 million kokanee of the early spawning variety were introduced into the lake (Table 7). They originated from Island Park and Anderson Ranch Reservoirs in southern Idaho. In 1976 and 1977, 1.6 million fry of the late spawning variety from Whatcom Lake, WA were released into the lake.

Table 3. Kokanee biomass estimated by age class collected in Coeur d'Alene Lake with a mid-water trawl during September 1979.

Year-class	Age	Mean weight(g)	Biomass(kg)	Density(kg/ha)
1978	0+	1.12	1,680	.17
1977	1+	34.38	78,730	8.16
1976	2+	65.76	117,710	12.20
1975	3+	120.29	55,333	5.74
Total			253,453	26.27

Table 4. Mean live weights (g) and instantaneous growth rates of kokanee collected in Coeur d' Alene Lake during 1979 by mid-water trawl.

	Mean weight (q)						Instantaneous
Aqe	30 May	21 June	25 July	16 Aug	25 Sept	22 Oct	growth rate
0+		.08	.23	.49	1.12	1.18	2.69
1+	10.12	10.96	18.91	24.44	34.38	38.66	1.34
2+	48.32	47.73	47.98	55.13	65.76	66.42	0.32
3+		81.08	79.51	94.94	120.29	124.83	0.45

Table 5. Mean distance and number of circuli to the first annulus of the 1976 and 1977 year-classes of kokanee collected in Coeur d'Alene Lake.

Year-class	(n)	Age	_Mean length (mm)	Mean distance to first annulus (mm x 41.6 X)	Mean no. of circuli to first annulus
1976	28	1+	164.7	17.4	13.1
1977	53	1+	159.1	16.0	12.8

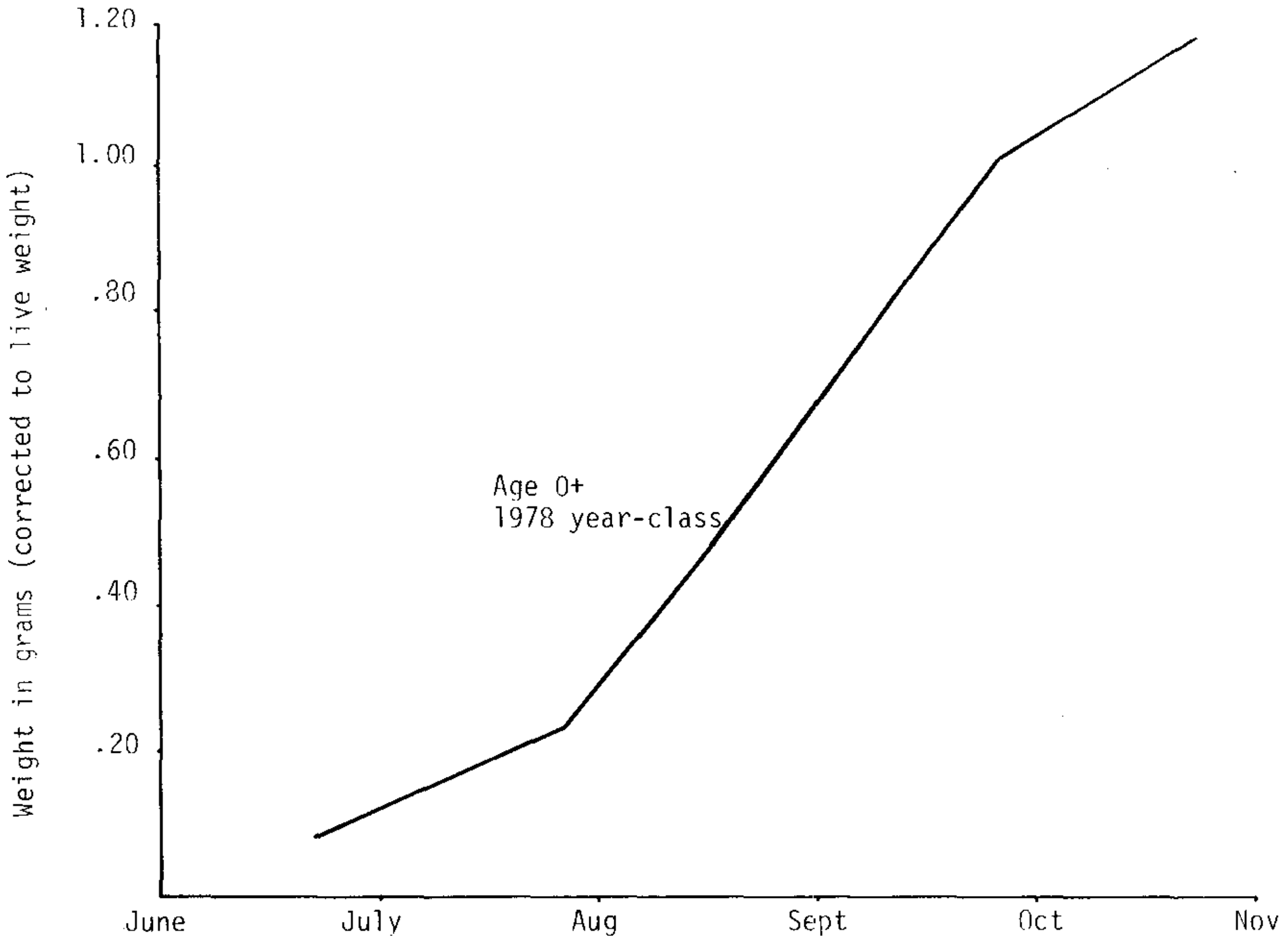

Figure 2. Mean weight (g) of age 0+ kokanee collected by month in Coeur d'Alene Lake during 1979 using a mid-water trawl.

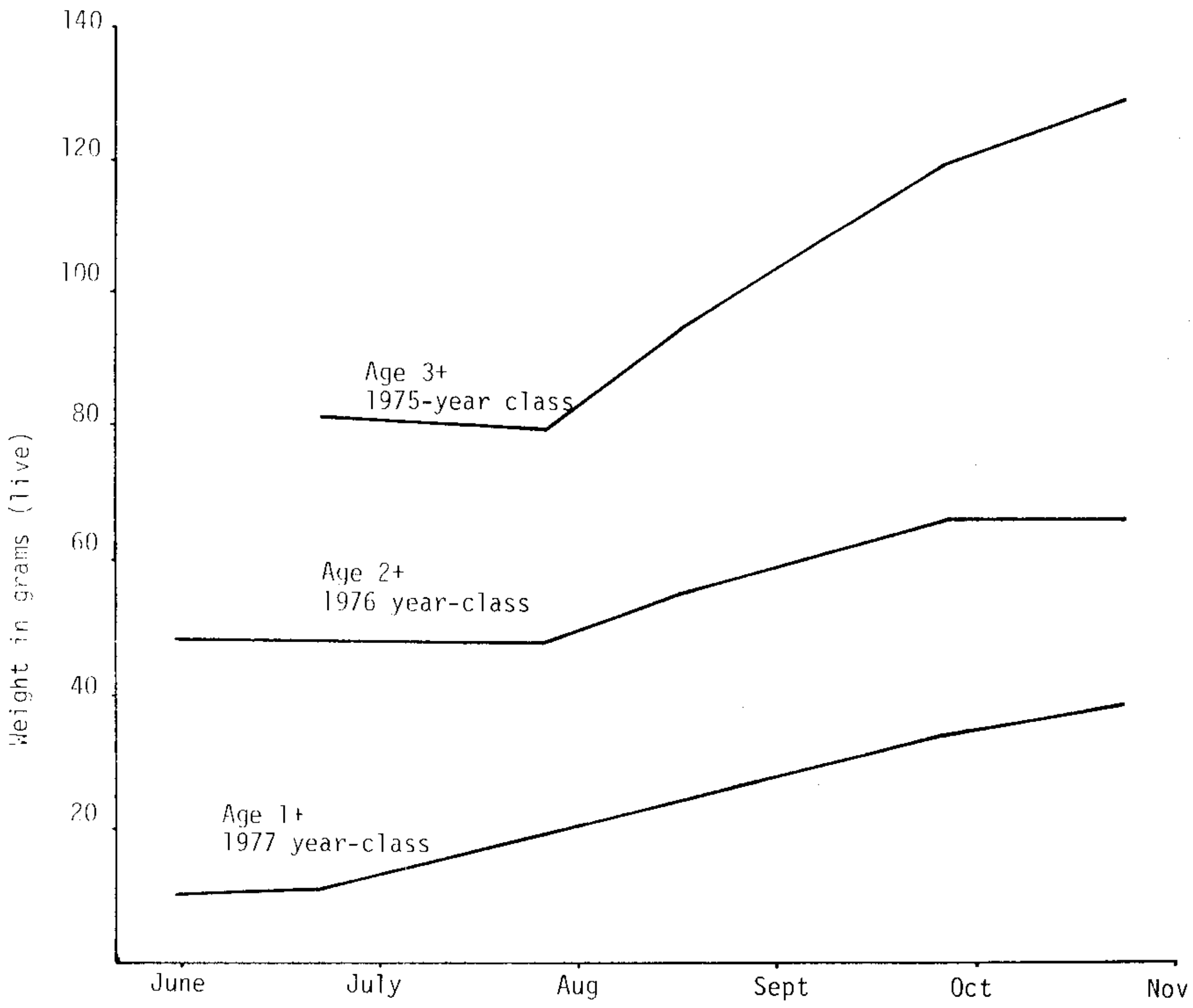

Figure 3. Mean live weights (g) of age 1+, 2+ and 3+ kokanee collected by month in Coeur d'Alene Lake during 1979 using a mid-water trawl.

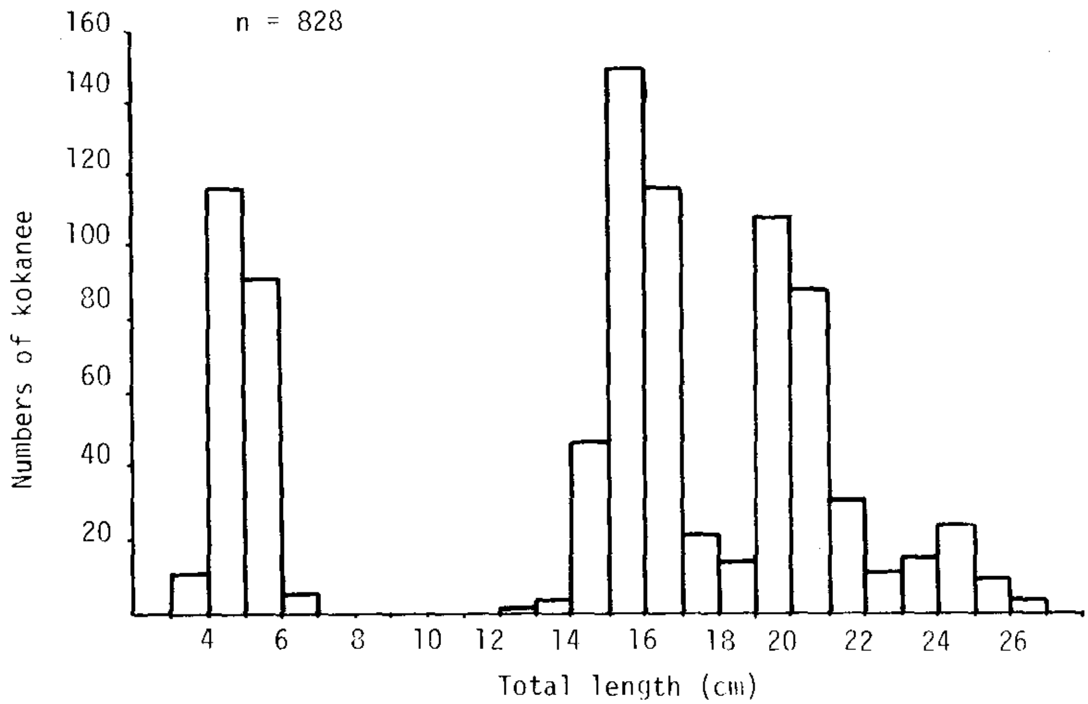

Figure 4. Length frequency of kokanee collected by mid-water trawl in Coeur d' Alene Lake during September 1979.

Table 6. Mean lengths of spawning age kokanee, by sex, from Coeur d'Alene Lake, 1954 to 1979.

Year	Males length mm	(in)	Females length mm	_(in)	Year	Males length mm	(in)	Females length mm	(in)
1954	409	(16.1)	381	(15.0)	1965	292	(11.5)	282	(11.1)
1955	371	(14.6)	361	(14.2)	1966	--		--	
1956	--		--		1967	318	(12.5)	302	(11.9)
1957	399	(15.7)	343	(13.5)	1973	329	(13.0)	309	(12.2)
1958	363	(14.3)	361	(14.2)	1974	312	(12.3)	296	(11.7)
1959	335	(13.2)	330	(13.0)	1975	276	(10.9)	276	(10.9)
1960	340	(13.4)	325	(12.8)	1976	--		--	
1961	328	(12.9)	315	(12.4)	1977	262	(10.3)	259	(10.2)
1962	292	(11.5)	287	(11.3)	1978	262	(10.3)	253	(10.0)
1963	274	(10.8)	269	(10.6)	1979	245	(9.6)	240	(9.4)
1964	279	(11.0)	269	(10.6)					

DISCUSSION

Acoustic vs. Trawl Estimate in Coeur d'Alene Lake

We obtained very similar population estimates using acoustic and mid-water trawl gear in Pend Oreille and Priest Lakes from 1977 through 1979 (Bowler 1979a, Bowler 1980). In Coeur d'Alene Lake during 1979 our acoustic estimate was 70% of the trawl estimate which is partially attributable to the difficulty in counting high density echograms (Bowler 1975). We make our quantitative estimates during August and September when kokanee are restricted to a narrow vertical distribution in the water column at night (Bowler 1975). If fish densities reach 500/ha (200/acre) during this time period there is considerable target overlap and a tendency to underestimate density. Priest and Pend Oreille kokanee densities ranged from 21 to 254/ha (9 to 103/acre) while Coeur d'Alene supported 626/ha (253/acre).

Kokanee Introductions and Population Success

Kokanee were first introduced into Coeur d'Alene Lake in 1937. Since then releases were made almost yearly. Kokanee began appearing in noticeable numbers in the catch in the late 1950s and early 1960s. By 1967 242,000 kokanee were harvested from the lake (Mallet 1968). It was felt throughout those years that hatchery releases were sustaining the fishery but it became obvious by the mid-1970s Coeur d'Alene was supporting viable natural reproduction. By the late 1970s Wolf Lodge Bay was yielding high densities of kokanee fry. At least 76%) of the lake's recruitment came from Wolf Lodge Bay in 1979. Wolf Lodge Bay was the release point of many of the kokanee introductions.

Hassemer and Rieman (this report) and Rieman (1980) discuss the unique qualities of Wolf Lodge Bay as a kokanee spawning, incubation and nursery area. It will be necessary to maintain water quality and spawning habitat in the hay if present yields are to be maintained.

Kokanee Abundance, Yield Predictability and Stock Recruitment

Coeur d'Alene Lake supported a high yield kokanee fishery during 1979. Anglers harvested 3.84 kg/ha (3.42 lb/acre) from the lake which compared to 103 kg/ha (.92 lb/acre) from Pend Oreille Lake and 0.10 kg/ha (.09 lb/acre) from Priest Lake. Pend Oreille was considered a moderate yield kokanee fishery during 1979 while Priest Lake a very low yield fishery. Recruitable age kokanee to the fishery for each lake was also commensurate with yield to the angler. Coeur d'Alene supported a total density of 157 recruits/ha (64/acre), Pend Oreille 46 recruits/ha (19/acre) and Priest Lake 12/ha (5/acre) .

Fishing success should continue to increase through the 1981 fishing season based on the strength of the 1976 and 1977 kokanee year-classes. Anglers harvested approximately 50% of the 1975 kokanee year-class during 1979 (Rieman 1980) . The fall estimate for the 1975 year-class measured .46 million which would have equaled approximately 1 million fish in the spring before fishing mortality began. The 1976 kokanee year-class was estimated at 1.8 million and the 1977 year-class equaled 2. 3 million. Considering natural mortality both estimates would suggest that fishing success should improve in 1980 and 1981 over 1979. The strength of the 1978 year-class was measured at 1.5 million indicating a reduced number for the 1982 fishing season.

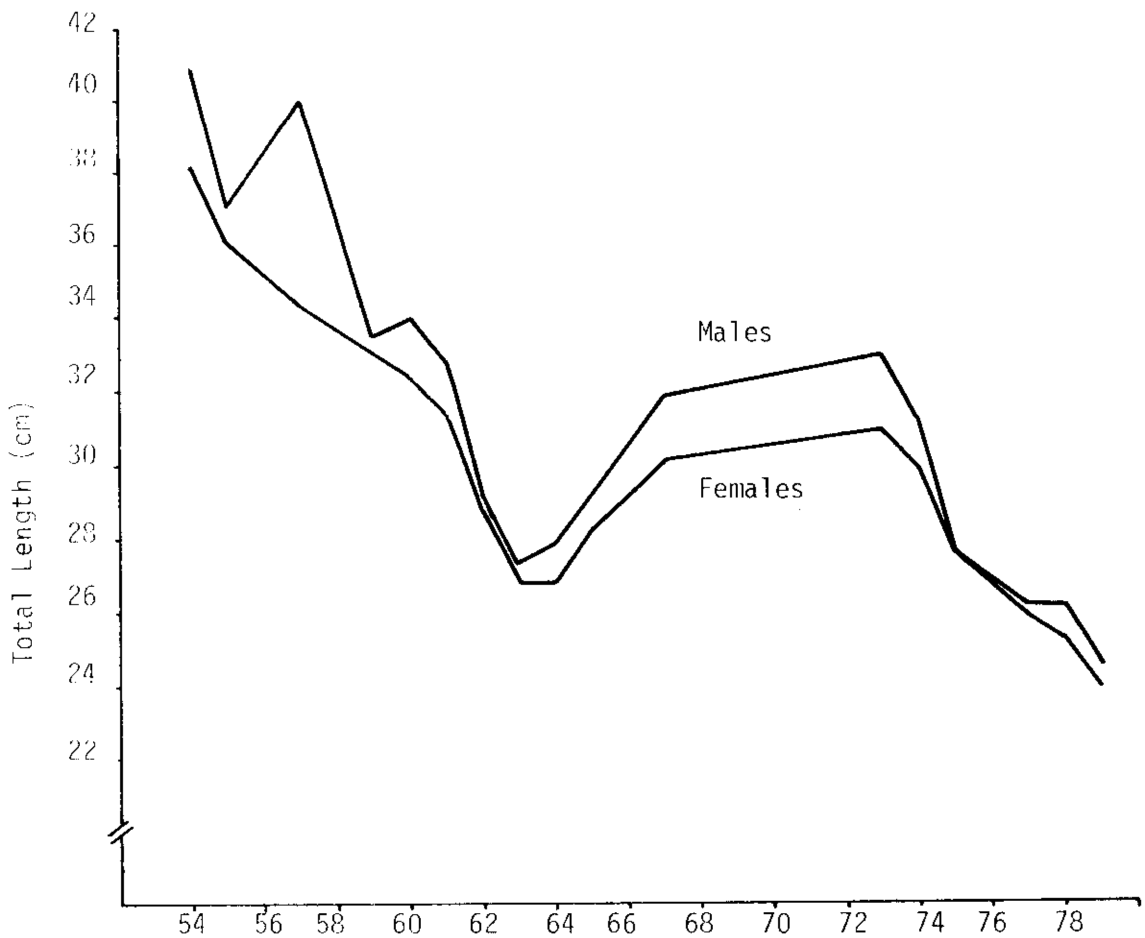

Figure 5. Mean lengths of kokanee spawners measured in Coeur d'Alene Lake from 1954 to 1979.

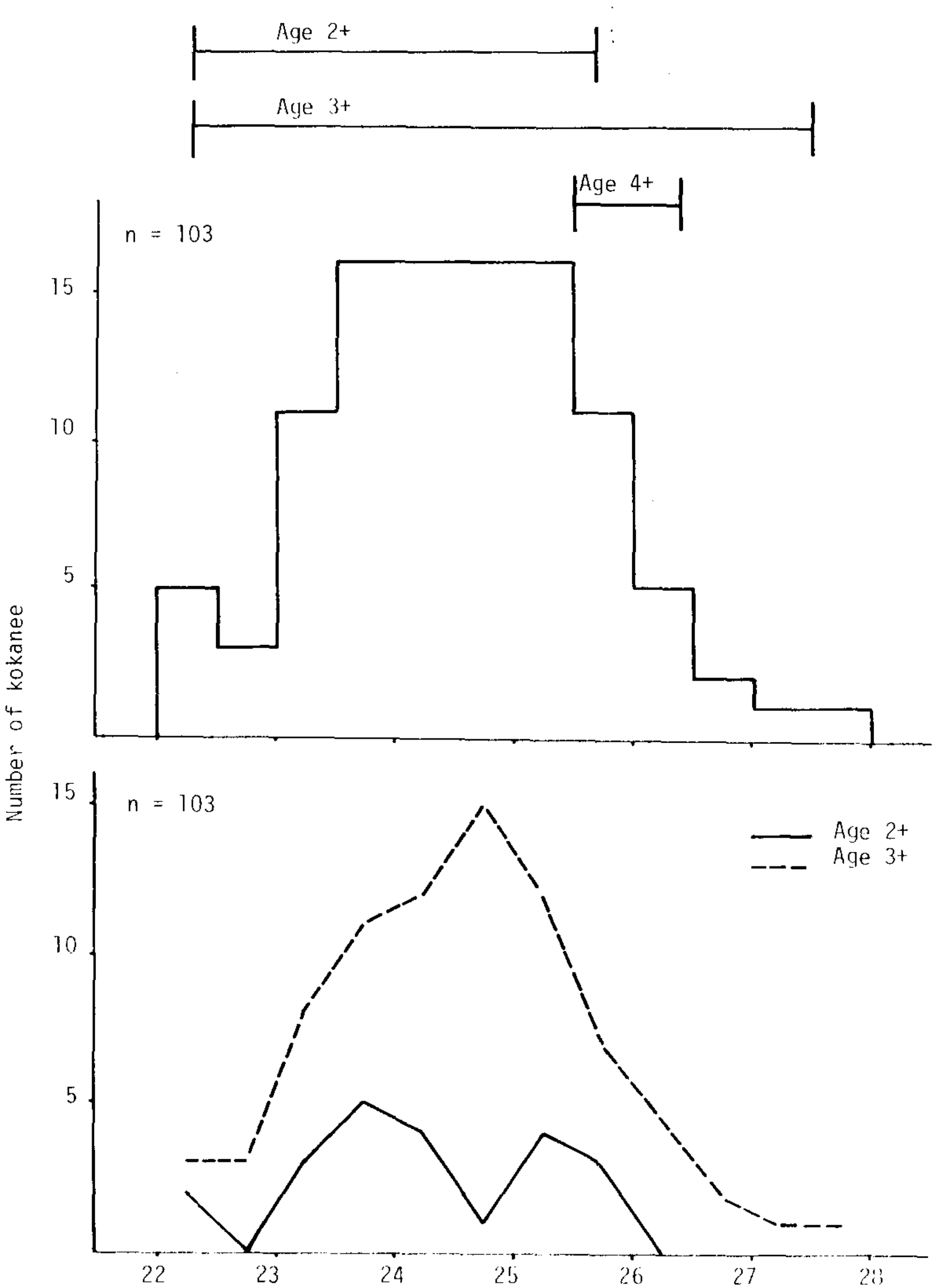

Figure 6. Length and age frequency of 103 mature kokanee collected from Coeur d'Alene Lake during 1979.

Table 7. Numbers of kokanee released in Coeur d'Alene Lake and/or tributary streams since introduction.

Year	Total number of fish	Year	Total number of fish
1937	35,000	1958	608,000
1938	150,000	1959	920,000* (488,000)
1939	259,000	1960	1,128,000
1940	---	1961	1,304,000
1941	187,200	1962	750,000
1942	854,690	1963	226,090
1943	--	1964	113,856
1944		1965	615,317
1945	--	1966	725,305
1946		1967	1,166,422
1947	42,000	1968	1,004,857
1948	100,000	1969	448,368
1949	219,150	1970	1,089,820* (639,345)
1950	202,500	1971	1,322,144* (506,664)
1951	533,600	1972	666,528* (231,016)
1952	175,000	1973	* (209,000)
1953	126,000	1974	* (793,455)
1954	124,000	1975	* (539,050)
1955	365,400	1976	1,200,500**
1956	314,488	1977	354,485**
1957	832,896		

*Parenthesis includes the number of the total fish that were from a strain of early spawning kokanee.

**Late spawning variety originating from Whatcom Lake, Washington.

Coeur d'Alene Lake has the potential for maintaining a high sustained yield kokanee fishery. It supports a high quality food base that has not been affected by the successful introductions of Mysis relicta as have Priest and Pend Oreille Lakes. It also does not have a major predator specie as does the other two lakes which has contributed to population declines of kokanee in both systems (Ellis and Bowler 1979, Bowler 1979b). Because of the nature of the shoreline spawning areas and the depth at which kokanee were found spawning in the lake, winter drawdown problems appear less severe than observed in Priest and Pend Oreille Lakes. The primary source of mortality is likely due to exploitation. Coeur d'Alene Lake is easily accessible and supports a highly efficient handline fishery (Rieman 1980).

With a stable or increasing kokanee population it will be necessary with future years of data to describe a sustained yield per recruit relationship that will enable anglers to enjoy a continuous high yield fishery.

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Coeur d'Alene Lake Spawn j g Evaluations ABSTRACT

Major kokanee spawning areas were delineated in Coeur d'Alene Lake by locating areas of major fry recruitment. Areas of highest fry recruitment during spring were surveyed during the spawning season to detect spawning activity. SCUBA dives were made in areas of major spawning activity to describe the depth range and substrate type where embryos were found deposited in the gravel.

Snorkeling of transects in the Coeur d'Alene River was done during July and September to locate kokanee.

In excess of 76% of the fry recruitment in Coeur d'Alene Lake originated from Wolf Lodge Bay on the north end of the lake. Subsequent fall-winter surveys revealed heavy spawning activity in the head of this bay. Concentrated spawning activity was observed on steep, road-fill slopes in areas of Wolf Lodge Bay to depths of 20 m (66 ft), with no obvious depth preference. Substrate in the road fill areas was composed of large angular material up to 150-mm (6 in)dimension. The importance of Wolf Lodge Bay for fry recruitment to Coeur d'Alene Lake may he a result of spawning in the road fill materials. The high porosity of this artificial substrate may enhance inter-gravel survival by providing increased water circulation through the gravels.

Mid-summer snorkeling revealed kokanee in pools several miles above and below Prichard on the Coeur d'Alene River. No kokanee were observed in the river while snorkeling transects during September.

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OBJECTIVES

To arrive at an index of relative abundance of spawning kokanee in Coeur d' Alene Lake and compare them with previous trend counts.

To relate lake water levels to lakeshore spawning kokanee.

TECHNIQUES USED

Major spawning areas of Coeur d'Alene Lake were located by sampling newly emerged fry throughout the lake during May and June 1979. A mid-water trawling system (Bowler, this report) was used to estimate fry density.

Areas of highest fry recruitment the previous spring were surveyed during the 1979 spawning season. The shoreline was inspected weekly by boat to detect spawning activity (physical disturbance of substrate, aggregation of mature fish, presence of dead and/or spent fish). SCUBA dives were made in areas of major spawning activity to describe the depth range and substrate type where embryos were found deposited in the gravel. Depths were recorded using a Dacor wrist-type depth gauge. Gross substrate analyses were made visually and included size composition of materials, degree of siltation and slope of substrate.

Kokanee were located in the Coeur d'Alene River by snorkeling during July. Attempts were made to collect fish by concussion sampling.

FINDINGS

Results of the mid-water trawling indicated that at least 76% of the fry recruitment in Coeur d'Alene Lake originated from Wolf Lodge Bay on the north end of the lake. Subsequent fall-winter surveys revealed heavy spawning in the head of this bay, with sparse activity on available beach gravel throughout the remaining portion of the bay.

Spawning was first recorded on 26 November when redds were observed in shallow, shoreline areas of Wolf Lodge Bay. Spawning in these areas was primarily in water less than 1 m (3.3 ft) in depth and substrate size ranged from approximately 5 to 30 mm (.2 to 1.2 in). SCUBA diving on 6 December revealed concentrated spawning activity from 1 to 20 m (3 to 66 ft) in depth on road fill slopes along Mineral Ridge (southeast end of Wolf Lodge Bay). Concentrated spawning was also observed on a similar road fill slope on the north shoreline of Wolf Lodge Bay on 20 December to a depth of approximately 18 m (60 ft). Fish spawning in these areas exhibited no apparent depth preference for egg deposition. Substrate on the road fill slopes is composed of large angular material up to 150-mm (6 in) dimension and angle of the slopes was approximately 60^0. No sedimentation of gravels was observed in any of the road fill areas.

Kokanee were reported in the catch of fishermen on the Coeur d'Alene and St. Joe Rivers. Mid-summer snorkeling revealed kokanee in pools several miles above and below Prichard on the Coeur d'Alene River. We were unsuccessful in collecting kokanee by concussion sampling. No kokanee were found in a second sampling trip during September.

DISCUSSION

Kokanee spawning to 20 m (64 ft) in Coeur d'Alene Lake appears to be a unique situation. Although shoreline spawning stocks of kokanee and sockeye are common, most available information indicates that spawning is limited to shallow water. Olsen (1968) reported sockeye spawning at depths less than 6 m (20 ft) in Iliamna Lake, Alaska. Lindsay and Lewis (1978) found kokanee spawning at depths less than 1 m (3. 3 ft) in Odell Lake, Oregon. Spawning was restricted to the upper beach areas (to 1 m in depth) of Priest Lake, Idaho (Hassemer and Rieman 1979). Stober et al. (1979) found in Banks Lake, Washington, kokanee spawned at depths of 1 to 16 m (52 ft) along natural lake slopes. Most of the spawning in Banks Lake was concentrated in the upper 4.5 m (15 ft).

The shoreline habitat in the head of Wolf Lodge Bay where deep spawning was observed is unique in that it was modified by encroachment of road construction during the 1950s. Alteration has occurred along both sides of the bay. Shoreline along the altered section is typically *very* steep (natural angle or repose) and consists of varying sizes of angular fractured fill materials.In several places highway fill extends well into the lake creating steep boulder-gravel slopes that are as deep as 25 m (82 ft). In these areas spawning was observed to depths of 20 m (66 ft) with no obvious depth preference. Egg deposition occurred on materials up to 150-mm (6 in) that was too large for fish to excavate during redid construction. In this situation spawning appeared to be more " broadcast" in nature than the typical redd construction observed on smaller substrate materials. Although steep slopes were used for spawning, much of the egg deposition occurred on narrow benches or downslope from larg[e] boulders where a shallow substrate gradient existed.

The road construction along the shoreline of Wolf Lodge Bay and the type of bottom material may be critical to providing useable deep water habitat. In the unaltered portion of Wolf Lodge Bay and also in our observations on Priest Lake (Hassemer and Rieman 1979) suitable spawning gravels did not exist below several meters in depth. Porosity of the fill material probably provides an excellent exchange of water through the substrate. Olsen (1968) found sockeye lake spawning in fine gravels and sand where upwelling ground water was present, but only in large rubbles where upwelling was not present. Olsen suggested that. the porosity of the large materials was important to provide good water exchange by normal lake currents. The steep slope of the Wolf Lodge Bay shoreline areas also increases the ratio of bottom area to lake surface area and may serve to reduce the level of sedimentation.

The information from Wolf Lodge Bay is encouraging in light of increasing water demands for downstream hydroelectric projects. First it shows that successful kokanee spawning can occur well below the zone of water level fluctuation on lakes with outlet control structures. The evolution of Wolf Lodge Bay as the major fry recruitment area in Coeur d'Alene Lake suggests that survival in that area has been superior to other areas of the lake. The annual drawdown of Coeur d'Alene Lake during the winter peak power demand period has undoubtedly made other lakeshore habitat less suitable for spawning. A simulation model (Hassemer and Rieman 1979) indicates that operation of a similar control structure on Priest Lake, Idaho caused a 4 to 37:? loss of kokanee embryos in the gravel in any year, with a potential loss of 907 in a worst possible situation.

The information is also important because it indicates that spawning habitat can be artificially created. The use of large materials forming a steep slope may be the key. An overcast of smaller gravel of suitable spawning size can provide the necessary substrate.

The presence of kokanee in the St. Joe and Coeur d'Alene Rivers during the summer is unexplained. We initially felt that the presence of fish in the rivers was an early pre-spawning run. However, we were unable to collect any fish to determine maturity and spawning has not been documented. The density of aye 0+ kokanee was very low in the south end of Coeur d'Alene Lake indicating that the rivers were not providing any significant recruitment.
A significant fishery does develop for kokanee at Cataldo on the Coeur d'Alene River in late spring. It would not appear, however, that the fish moving into the river have a significant influence on juvenile recruitment to the lake.

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